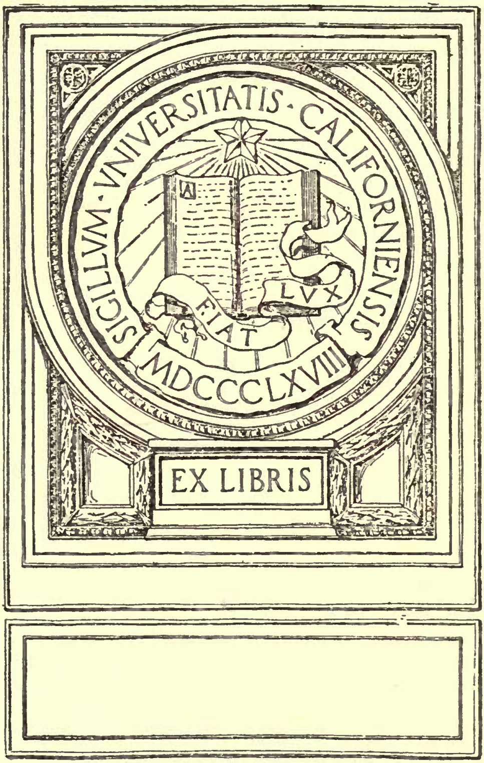
Common Commodities and Industries

Stones and Quarries

J. Allen Howe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STONES AND QUARRIES

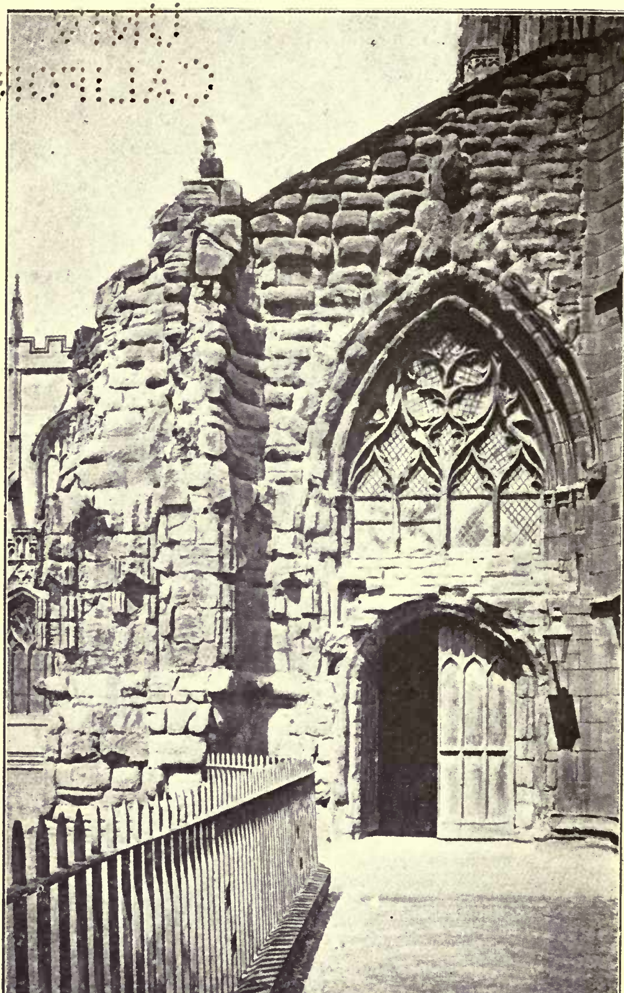

Photo by Valentine *Dundee*

WEATHERED SANDSTONE, CHESTER CATHEDRAL

Frontispiece

PITMAN'S COMMON COMMODITIES AND INDUSTRIES

STONES AND QUARRIES

BY

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LONDON : SIR ISAAC PITMAN & SONS, LTD.
BATH, MELBOURNE & NEW YORK

Printed by Sir Isaac Pitman
& Sons, Ltd., London, Bath,
Melbourne and New York

PREFACE

In this small volume an attempt has been made to place before the reader a broad general view of the stone industry, to show what part it plays in the life of the community and to give an outline of the methods and machinery employed in its development.

Within the limits assigned to the books in this series it has not been possible to do more than indicate in the briefest way the main features of this great industry and to point out some of the characters of the commodities handled therein. There are branches of the stone industry that take so prominent a place in the activities of civilized nations that separate treatment is required to do them justice, thus Cement manufacture, which obtains its raw material largely from quarries, forms the subject of a separate volume.

A certain vagueness about the natural boundaries of the subject will be observable, and such questions as What is to be included in "Stone"? or, Is a stone-mine to be regarded as a quarry? have been answered by the light of convenience rather than that of logic or consistency.

The author desires to express his grateful thanks to the following firms who have kindly given assistance with illustrations: The Bramley Engineering Co., Ltd., Crosby Lockwood & Co., John Freeman & Son, Ltd., the Council of the Geologists' Association, Hadfields, Ltd., the Hardy Patent Pick Co., Ltd., Ruston & Hornsby, Ltd., the Sullivan Engineering Co., and the proprietors of the journals: the *British Builder*, the *Quarry*, and the *Stone Trades Journal*.

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STONES AND QUARRIES

CHAPTER I

THE STONE INDUSTRY

FROM small beginnings in the remote dawn of man's development the Stone Industry has progressed, not without lapses and periods of retardation, until to-day it has become one of the great fundamental industries in every part of the world.

In the very earliest epochs, long anterior to the first page of history, in what is termed the "Stone Age," men sought out hard stones and from them fashioned their rough domestic tools and their weapons of war and the chase. Probably in those days stone had a higher value than it has ever had since. The earlier implements of stone were rude and unfinished, later they came to exhibit the extraordinary dexterity of their makers and often possessed great beauty of form. This employment of stone gradually gave place to metals, yet it has lingered with the more inaccessible savage races until recent times.

It is in Egypt that we obtain the clearest and longest view of the early stone industry; by the relics left behind, the various civilizations that succeeded one another in that region have been traced with considerable accuracy. Somewhere about 10,000 years ago the inhabitants of Egypt were making implements of flint and with simple tools of stone were forming out of the same material vases and similar vessels ; a little later we find them

selecting rare and beautiful hard igneous rocks for this purpose and trading in *lapis lazuli* and serpentine for ornamental treatment.

In the later stages of the pre-historic period, still more than 7,000 years ago, emery was regularly employed for grinding and polishing vases, beads and other objects, the finest work being put into the hardest stones. Vases were shaped by chipping and polished, not on lathes, but by rubbing; they were hollowed out by grinding with a stone with water and sand or emery. Flint implements were made by flaking and even by grinding to the required form and then re-flaking to give the cutting edge; some of the flaking is so fine and regular that as many as forty serrations to the inch have been counted. Delicate personal ornaments, such as armlets, were fashioned out of flint.

With the incoming of the Dynastic race came the carving of colossal figures in stone like those of the god Min, still remaining at Koptos, or the scene representing Semerkhet conquering his enemies, cut in the sandstone rock at Sinoe. Choice hard stones, porphyry, syenite, rock crystal, continued to be shaped into vases; these were still ground out as before, but tabular drills either set with hard stones or plain, for use with emery or sand were employed early in the Dynastic period. Saws for cutting stone, differing little from some of our own were then in use. The finest masonry was achieved in the fourth Dynasty, about 3,800 B.C., when massive stone work was undertaken in the most lavish manner and executed with astonishing accuracy. It is said that the stone-work in the pyramid of Cheops (Khufu) has an average error of only one in 15,000 in length and even less in angle. In the work of later dynasties this degree of accuracy was not attained. The wonderful stone structures, both great and small

of these early epochs are too numerous for description; one may cite such examples as the monuments of Rameses at Thebes, the Temple at Luxor and the Temple of Ammon at Karnack, built by Thothmes III about 1460 B.C. Nearer home may be seen on the Thames embankment "Cleopatra's" Needle, which was raised by the same monarch in Heliopolis, whence it was removed by Caesar to Alexandria, before it eventually reached its present site.

The technical skill and the will to execute stone-work passed away from Egypt, but we find the traditions conserved, though modified in various ways, in the wonderful masonry of Crete, in the carvings of Asia Minor and Persia, and in the remarkable development of refinement and style in Greece.

Buddhist stone-work in India should not pass unnoticed; one of the finest examples, the carved gateway of Bhilsa, was executed about 250 B.C. Mohammedan stone-work in the same country is represented by some wonderful examples of which the Taj Mahal is perhaps the best known. Fine work was done in the period of Arab ascendancy and on another plane, but quite remarkable, is the masonry and carving of the early inhabitants of Mexico and Peru.

The Romans were great users of stone and understood it well; they built much, in a rather ponderous manner, and in the later periods used enormous quantities of marble both for building and decoration.

In mediaeval times the most important application of stone-work in Europe was to ecclesiastical architecture and in a lesser degree to the erection of private castles and the walling of towns.

Before modern times the quantity of stone required for purposes other than construction was quite small; now great quantities are required for other uses as well.

Statistics relating to the stone industry are very imperfect, but the figures given below will give a rough idea of its range and magnitude.

From the quarries and stone-mines of Great Britain in 1913 the production and value of the more important stones was—

	Tons.	Value at Source in Pounds.
Limestone[1] . .	12,740,664	1,369,168
Chalk . . .	4,858,126	213,479
Igneous Rocks .	7,098,493	1,386,022
Sandstone . .	3,977,303	1,143,431
Gravel and Sand .	2,409,152	184,518
Slate . . .	370,756	926,739
Chert and Flint .	74,858	12,781
Gypsum . . .	285,338	90,450
China Stone . .	66,626	32,402
Clay and Shale. .	13,859,821	1,778,071

No figures are available to show how these materials were used, but the table given below for a single group, Gravel and Sand, shows how these materials were distributed for different purposes in the United States (1913), and will serve to illustrate the character and magnitude of the industry.

Glass Sand	1,791,800
Moulding Sand . .	3,563,538
Building Sand . . .	25,397,383
Grinding and Polishing Sand	941,373
Fire and Furnace Sand .	519,061
Engine Sand . . .	1,033,450
Paving Sand . . .	3,335,508
Railway Ballast Sand .	2,335,196
Sand for other purposes .	2,111,997
Gravel	38,526,498
Total . . .	79,555,849 Short Tons

[1] *Mines and Quarries.* Home Office, H.M. Stationery Office 1914.

In Great Britain the stone produced in 1909, according to the Census of Production, was distributed in the following manner—

	Tons.
Building Stone	1,750,000
Monumental Stone	30,000
Setts and Paving	680,000
Road Metal	4,000,000
Grindstones and Mill stones	30,000

The rest of the output was unclassified; it includes over 3,000,000 tons of stone employed for lime.

In Great Britain there are about 10,000 open quarries and many smaller ones besides. In France there are about 40,000 quarries, some being underground. The number of persons employed in Great Britain in and about quarries is 80,000, more or less; and the weight of explosives used annually is over 5,000,000 pounds, of which something like 80 per cent. is gun-powder.

Imperfect though these figures are, they serve to show in outline the relationship of quarrying to the needs of the community, and point out some of the first main lines of distribution from quarry to consumer.

In the following pages it has been necessary to give a certain latitude to, and at the same time impose restrictions upon, the interpretation of "stone" and "quarry," in order to keep within the field of what is commonly understood by these terms. There are both stones and quarries that could not legitimately be included; stones such as "gem-stones," "gall-stones," "iron-stone," and quarries operated for "minerals" (mica, asbestos, corundum, etc.), or for "ores" (ironstone, copper, gold).

CHAPTER II

ROCKS, STONES AND MINERALS

Before one can appreciate the qualities of different classes of stone it is desirable to have a conception of the nature of *rocks*, of which *stones* are relatively small pieces. Geologists regard the whole of the crust, or outer part of the earth, as consisting of rocks, and in this sense the term embraces all the kinds of non-living matter that make up the crust, whether they are hard and coherent like granite, soft like some clays, or incoherent like sand. Even water may logically be regarded as a rock according to this view, indeed, in the polar regions vast masses of ice do constitute part of the solid crust. On the other hand what are obviously solid rocks when cold may exist in parts of the crust as fairly mobile liquids, if their temperature is sufficiently high, as may be observed in many of the regions where there are active volcanoes.

It is evident, therefore, that all rocks do not yield stones, though in a literary sense the terms may be synonymous; no one thinks of calling a lump of soft clay or a handful of sand a stone, but with these and a few other exceptions a stone may be a piece of any kind of rock; and "stone" according to common commercial usage is rock capable of some human application.

Kinds of Stone—Minerals. The petrologist, whose province is the special study of rocks, is able to recognize an almost endless variety, to many of which specific names have been given. The names have been applied to differentiate rocks having peculiarities of texture, structure or chemical and mineral composition.

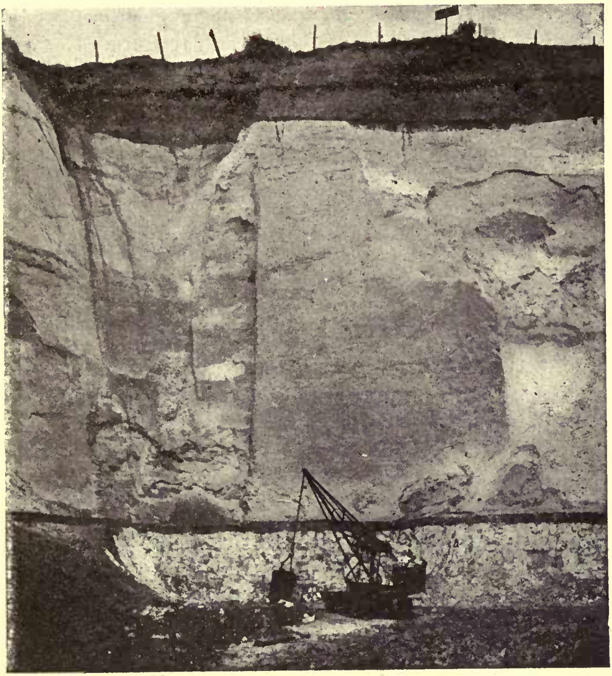


Fig. 2

TUFF AND HOAR'S PIT, PLUMSTEAD

A quarry in composite material, showing in descending order—

Blackheath Pebble-beds	up to 9 ft.
Woolwich loam and pebbles	„ 7 „
Thanet Sands	„ 66 „
"Bull-head" a dark band	„ 1 „
Chalk	„ 8 „

It is, however, quite unnecessary to burden the mind with the names of a large number of rock types because only relatively few rocks are employed as stones for industrial purposes. But when it is required to study the comparative fitness of stones for specific purposes a knowledge of petrology and the methods employed in this branch of science is frequently necessary.

All rocks are composed of *minerals*, which are bodies possessing, within certain limits, constant chemical composition and constant physical properties, such as specific gravity and optical properties, and very often a definite crystalline structure and form. Some rocks are composed essentially of one mineral, such are the purer limestones and sandstones, others are made up of a mixture of minerals. Descriptions of minerals are given in works on Mineralogy; only a few require a brief mention here on the ground that they play an important part in the formation of common stones or because they appear in some stones as bodies detrimental to their use.

Minerals are described as primary when they are original constituents of a rock, and secondary when they have formed within the rock during subsequent changes. The same mineral may appear both as a primary and secondary constituent. Secondary mineralisation has often an important bearing on the commercial utility of stone.

Quartz. Silicon dioxide, SiO_2 (Silica). Hardness 7. Specific gravity 2·65. Fracture conchoidal, usually colourless or white, but may be tinged with almost any colour ; transparent or opaque. Crystallizes commonly in hexagonal prisms terminated by pyramids. Fuses to a pasty mass about 1,600°C. Insoluble in acids except hydrofluoric acid.

Quartz is one of the most abundant minerals ; it is an

essential constituent in granites, gneisses and schists, and the acid igneous rocks and is found as a secondary mineral in many others. It forms the bulk of sands and sandstones in the form of grains derived from pre-existing igneous, metamorphic and sedimentary rocks. It also occurs as veins, often carrying valuable ores, traversing other rocks. Quartz crystallizes out from hot or cold aqueous solutions and during the solidification of igneous magmas, in which water always plays a part.

Silica occurs also in the form of *chalcedony*, without crystalline form and apparently, though not truly, devoid of all crystalline structure. It has the hardness of quartz with a waxy lustre. Variegated forms of chalcedony, often with different colours arranged in bands, are called *agate;* dark varieties with very regular banding are called *onyx;* an impure variety, opaque, and dull is *jasper*. *Flint* is a dull variety, usually black or dark-grey but occasionally white or reddish. It occurs abundantly as nodules and layers in parts of the Chalk formation and in gravels and shingle beds derived from it. *Chert* is a rougher form of flint with a more splintery fracture which is found occurring in a similar manner in the Carboniferous and other limestones also in the Greensand formation.

OPAL is a truly amorphous form of silica in combination with variable amounts of water. It is found filling cavities in rocks or as a cementing medium and it may take the highly coloured form of precious opal or may be a dull white stone.

GEYSERITE or SILICEOUS SINTER is a porous, pale-coloured rock composed of chalcedonic silica, which has been deposited by water containing much soluble silica, often assisted by certain algae.

DIATOMITE or KIESELGUHR is found as a lake or bog

deposit, formed by the activity of minute plants called diatoms, which secrete a delicate skeleton composed of opaline silica.

ROTTENSTONE is a fine-grained siliceous residue resulting from the weathering of impure limestone and cherts. *Tripoli* is a variety of rottenstone.

FELSPAR is the name of a group of anhydrous silicates, all intimately related by their chemical composition, form and physical properties. Together they make up about 60 per cent. of the earth's crust. They may be classed as follows—

1. *Orthoclase* and *microcline,* a silicate of alumina and potash, KSi_3O_8.
2. *Albite,* a silicate of alumina and soda, $NaAlSi_3O_8$.
3. *Anorthite,* a silicate of alumina and lime, $CaAl_2 Si_3O_8$.
4. *Alkali felspars,* mixtures of 1 and 2 (KNa) $AlSi_3O_8$.
5. *Lime-soda felspars,* mixtures of 2 and 3.

Orthoclase crystallizes in a different system from the other felspars, which are classed as plagioclase felspars, but the general crystal form is very similar in all.

A characteristic feature of all the felspars is a good cleavage in two directions nearly at right angles (90° in orthoclase). Fracture in other directions is uneven, but it is not easy to get. Hardness 6. The lustre is vitreous to pearly. The colours are mostly grey or white but moderate shades of red are common, particularly in orthoclase and the alkali felspars, sometimes they have a green tinge. They are usually opaque but occasionally transparent and glassy. The plagioclase felspars often exhibit on the cleavage faces a fine parallel striation due to a phase of crystal twining.

The MICAS are complex aluminous silicates, rarely forming perfect crystals, hexagonal prisms or pyramids, as

in some lavas and pegmatites, more often occurring as ragged scales or plates. They all possess a very perfect basal cleavage which enables them to be split into extremely thin elastic, tough and flexible laminae that are quite transparent. These qualities make the micas valuable

Fig. 3

PORPHYRITIC FELSPAR IN CORNISH GRANITE
A CRUCIFORM TWIN CRYSTAL

for many industrial uses, in electrical apparatus, compasses, lamp-chimneys, etc. They may be conveniently classed in two groups—

1. Alkali micas—" White micas " including Muscovite; and

2. Ferro-magnesian micas—" Black micas " including Biotite.

Muscovite and biotite are the more common; the former is more stable than the latter. Muscovite is found in granites, gneisses and mica schists, and is the mica usually present in sandstones. It is also a secondary mineral in many rocks resulting from the decomposition of felspars and other minerals, it then assumes a minute scaly condition known as *sericite.* Biotite occurs in the same rocks including some lavas and basic igneous rocks, but it is not common in sandstones because it is not sufficiently durable.

AMPHIBOLES and PYROXENES are two closely related groups of rock-forming minerals, the members of which are similar in chemical composition in their mode of crystallization and other physical properties. They are metasilicates, being salts of metasilicic acid H_2SiO_3.

The more important amphiboles are *Hornblende, Tremolite,* and *Actinolite.* They all have well-marked cleavages parallel to the faces of the prisms making angles with one another of 56° and 124°. They form elongated, blade-like crystals or short prisms, the cross-section of which is usually hexagonal. Their hardness is 5 to 6 and specific gravity 2·9 to 3·5. They contain lime, magnesia, and more or less iron; hornblende also contains some alumina and soda.

The more important pyroxenes are *Augite, Diopside, Enstatite,* and *Hypersthene.* Like the amphiboles they have two fairly good cleavages parallel to the prism faces, but they make angles of from 87° to 93°. They tend to form rather stumpy prismatic crystals the cross section of which is usually octagonal. They appear in rocks also as irregular grains.

THE HYDROUS SILICATES. *Chlorite, Talc, Serpentine, Kaolinite,* the *Zeolites.*

Chlorite is a mica-like mineral distinguishable by the fact that the cleavage plates are soft and inelastic. The colour is some shade of green. Hardness, 2·5 to 2·5. There are several varieties containing various amounts of magnesia, iron, hydrogen and alumina. It is common in igneous and metamorphic rocks.

Talc is an acid metasilicate of magnesium occurring in the form of plates or folia, rather like mica, or fibrous, or massive when it is called *Steatite* or *Soapstone*. The plates when present are inelastic, and the mineral is very soft and has a greasy lustre; hardness = 1. Its colour is pale-greenish or grey. It occurs in schists and as an alteration product in some of the more basic igneous rocks. Soapstone is a stone of considerable utility.

Serpentine is a hydrous magnesium silicate; it occurs either in small patches in rocks or massive or fibrous. Its colour is usually green but it may be brown, yellow or black; it is commonly opaque but may be translucent. It has a greasy feel and lustre. Hardness, 2·5 to 5·0. Serpentine is formed by the alteration of olivine, amphiboles and pyroxenes. Associated with calcite, dolomite and sometimes with magnesite in its massive state it forms several varieties of serpentine " marble " (p. 46). The fibrous form of serpentine is known as *chrysotile*, one of the most valuable " asbestos " minerals of commerce.

CARBONATES. Two carbonates are of importance: *Calcite* and *Dolomite*.

Calcite is a carbonate of lime $CaCO_3$, when pure it is colourless and transparent, usually it is opaque and often tinged with some colour. Whatever external form its crystals may take, and they are many, it always has three very perfect cleavages parallel to the sides of a rhombohedron, and it is rather difficult to break

except along the cleavage planes, which it does readily. It forms the bulk of all limestones and fine marbles and occurs as a cementing material in some sandstones and as a decomposition product it appears in many igneous rocks. Its hardness is 3; specific gravity, 2·72. It is readily soluble in cold dilute acids with effervescence.

Dolomite is a carbonate of calcium and magnesium, $CaMg\,(CO_3)_2$. Its hardness is 3·5 to 4; specific gravity, 2·85; lustre vitrious or pearly. The colour is occasionally pure white, but it is usually more strongly coloured than calcite owing to included impurities. It is often associated with calcite in limestones and marbles. The mineral may be distinguished from calcite by its very slow effervescence with cold dilute acid and brisk effervescence with warm acid.

GYPSUM, hydrous calcium sulphate ($CaSO_4\ 2H_2O$), occurs in several forms, in crystals or masses of crystalline folia, called *selenite,* fibrous as *satin-spar,* massive and granular as *rock gypsum* of which the finer kinds form *alabaster.*

Several IRON compounds occur in rocks, some are active colouring agents.

Magnetite. Fe_3O_4, black; hardness, 5·5 to 6·5; specific gravity, 5·16 to 5·18.

Haematite. Fe_2O_3, black to deep red, with a red streak; hardness, 5·5 to 6·5; specific gravity, 4·8 to 5·3.

Limonite. $2\,Fe_2O_3.\ 3\,H_2O$, colour some shade of brown or yellow. It is often the result of the oxidation and hydration of other iron-bearing minerals.

Pyrite and *Marcasite.* Iron disulphide, FeS_2, colour brass yellow, lustre metallic, occurs in small grains and crystals or as nodules with radiating fibrous structure, in many kinds of rocks. It is an injurious mineral in stones required for industrial purposes.

CHAPTER III

THE CLASSIFICATION OF STONES

In order to obtain a clear view of the relationship of the many kinds of rock some sort of classification is desirable, so long as it is remembered that the classification is merely a matter of convenience and that it may be kept quite simple or almost indefinitely extended.

We may take into consideration the mode of formation of the rocks and place them in three broad groups. (1) *Igneous* rocks, those formed directly by the agency of heat; (2) *Sedimentary* rocks, those formed by deposition under water or more rarely by the transporting power of wind; and (3) *Metamorphic* rocks formed by the alteration of the two preceding groups.

Igneous Rocks. In the first group the rocks are all frozen or solidified melts of rock matter; the cooling, "setting" or "freezing" may have taken place slowly, deep in the earth, under great pressure (plutonic conditions); or more rapidly while still surrounded by other rocks, but under more moderate pressures (hypabyssal conditions); or quite rapidly on or very near the surface of the earth, under little more than atmospheric pressure (volcanic conditions).

The rocks formed under these three sets of conditions have certain characters common to each, irrespective of their chemical composition. Thus the plutonic rocks are completely *crystalline;* the once molten material has not only solidified but has formed itself into distinct mineral substances, and these have grown into individual particles first of one kind then of another until the whole of the original liquid magma has become a solid intergrowth of mutually interfering crystalline

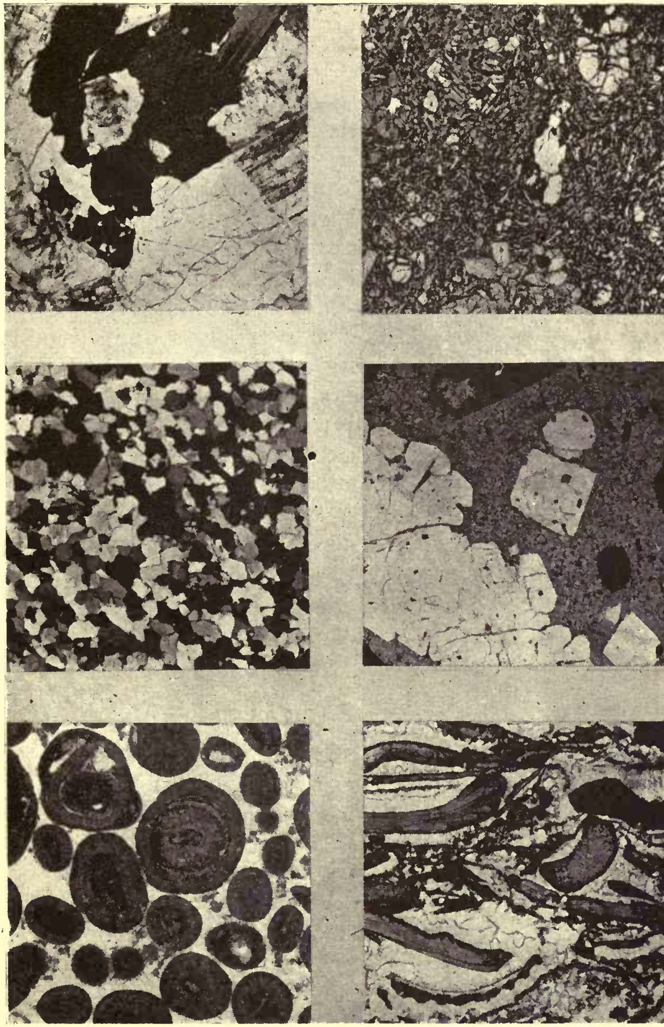
mineral grains. The typical rock of this kind is *Granite*, and its typical minerals are quartz, felspar and mica. Other rocks are *Syenite*, *Diorite* and *Gabbro*.

The rocks formed under hypabyssal conditions, that is, as "dykes" (vertical or highly inclined sheets), sills (horizontal intrusive sheets) and small masses (laccoliths), take an intermediate place, as regards texture, between those cooled from large deep-seated masses and the volcanic rocks, cooled at the surface. The coarser granular texture of granite is either imitated on a finer scale or it may be replaced by a sort of felt-work of small lath-shaped felspar crystals and microlites often with one or more of the other minerals appearing as larger, better developed individuals. Thus quartz, one of the felspars, mica, hornblende may be present as larger, more perfect crystals when they are said to be porphyritic and the rock itself is a *porphyry*.[1] The term *porphyrite* is employed by British petrographers to indicate a rock of this class corresponding in composition to the diorites. The more common types are *Granophyre*, *Felsite*, *Quartz-porphyry*, corresponding to the granite; *Porphyry*,[2] corresponding with syenites; *Porphyrite*, corresponding to the diorites and *Dolerites* and *Diabases* corresponding to the gabbros.

In volcanic rocks the differentiation of the liquid magma into definite minerals is less complete, some or all of it may have solidified as a glass containing few if any recognizable minerals, or the bulk of the material may have crystallized but never with the granular crystalline texture of granite. The volcanic rocks often show structures due to flow and movement while in a fluid state; they are often vesicular on account of the formation of steam and gas bubbles, an extreme case

[1] In the technical sense.

[2] In the petrological sense.



1 2

3 4

5 6

Fig. 4

TYPICAL STRUCTURES IN STONE

1. Granite. 2. Basalt. 3. Sandstone.
4. Granite-porphyry. 5. Oolitic Limestone. 6. Shelly Limestone.

is exemplified in *pumice stone.* In some types of volcanic eruption the material is blown out in the state of fine or coarse dust or larger fragments forming when it settles deposits of volcanic "ash" or "tuff," and breccica, constituting sedimentary strata but of volcanic origin. The volcanic rocks include *Obsidian, Pumice, Rhyolite, Felsite, Trachyte, Andesite, Basalt* and *Tuff.* Lava is a general term applied to flows of any of these rocks. Rhyolites, felsites and trachytes are usually pale rocks, andesites are grey or pale brown, basalts are dark. All of them may be porphyritic.

The igneous rocks are usually classified on a two-fold plan, according to their texture, and according to their chemical and mineral composition. In the following table some of the leading types of igneous rocks are arranged to show approximately their chemical relationships horizontally and textural relationships vertically, but it must be remembered that each type has characteristic textures and mineral associations of its own.

IGNEOUS ROCKS

Granite	Quartz Porphyry	Rhyolite	Glassy Rocks
Syenite	Porphyry	Trachyte	
Diorite	Porphyrite	Andesite	
Gabbro	Dolerite	Basalt	

The vertical arrow indicates *increasing* specific gravity and *decreasing* silica content.

The horizontal arrow indicates *increasing* fineness of grain and *decreasing* completeness of crystallization.

Sedimentary Rocks are derived directly or indirectly from pre-existing rocks, they occur in a few simple types

of deposit with almost complete gradations from one to another. The principal sedimentary rocks are *Sandstones*, *Conglomerates* (composed of rounded fragments), *Breccias* (made of angular fragments), *Clays*, *Shales*, *Limestones*, *Gypsum*.

Metamorphic rocks constitute a large and complex group which embraces altered or metamorphosed igneous and sedimentary rocks of all kinds. Rocks have changes wrought in them by (*a*) pressure, due to earth movements; (*b*) heat, due directly to the proximity of masses of hot rock and indirectly to the rise of temperature generated by earth movements; (*c*) the action of heated vapours and gases.

The changes wrought by these agencies have often an important influence on the industrial applicability of stones.

One of the common results of metamorphism is the production of banded structure within the rock caused by the separation of the mineral constituents into layers often lenticular, which may be broad or narrow, straight, or contorted.

When the banded rock consists of bands or layers of different mineralogical composition, recognizable by the naked eye, it is called a *Gneiss*, a term which in its broadest sense may be applied to rocks of any origin if they possess this structure.

Gneisses may be distinguished by their general composition as granite-gneiss, diorite-gneiss, gabbro-gneiss, etc., or by a predominant mineral, as biotite-gneiss, hornblende-gneiss.

When the rock consists of layers or folia of the same general composition it is called a *Schist*. In these rocks quartz is usually a dominant mineral associated with chlorite, mica, talc, or one of the amphiboles or pyroxenes.

Schists may graduate on the one hand into gneisses and on the other into *Phyllites*, fine-grained rocks with mica well developed in their folia so as to produce a fissility in the rock, and these may pass into *Slates*, fissile, fine-grained rocks in which the micacious cleavage surfaces are less obvious.

Another common result of metamorphism is the formation of an entirely new set of minerals out of the original material ; this is particularly evident in the rocks altered by contact with large igneous masses. Limestones are frequently altered by a process of recrystallization into marbles; sandstones are similarly converted to quartzites.

CHAPTER IV

LIMESTONES

General Characters. Rocks composed mainly of carbonate of lime are classed as limestones; they constitute a very widely spread and important group of stones. In the majority the carbonate of lime exists in the crystalline condition, calcite, and the stone consists of an aggregation of calcite particles which may be fairly large and easily recognizable, as in the statuary marble, or, they may be extremely small as in many compact limestones, when the stone appears to be composed of a calcareous mud or paste.

Like all sedimentary rocks, the limestones pass by insensible gradations into other types; a pure limestone is composed almost entirely of carbonate of lime, 98 to 99 per cent. is not uncommon; but impurities are present in varying degree, thus, most limestones contain some argillaceous matter, if this is considerable in amount they are called *argillaceous limestones*, and certain soft rocks of this character are known as *marls*. The impurity may be silica in a colloidal and cryptocrystalline condition, and a *siliceous limestone* of this kind may pass into a purely siliceous rock, "chert." Silica may also be present in the form of grains of quartz and such a *sandy* or *arenaceous limestone* by increase in the proportion of sand may become a calcareous sandstone. Other common impurities are iron oxides and carbonaceous matter, where these are present in sufficient amount *ferruginous* and *carbonaceous limestones* result.

Mode of Origin. Limestones are usually stratified rocks, they are found in "beds" where they have been deposited as sediment in the waters of seas and lakes,

but they differ from most muddy and sandy sediments in that the material forming the deposit is largely the product of the activity of living organisms, animals or plants.

Of the many kinds of living creatures that have contributed to the formation of limestones, corals, molluscs, and calcareous algae may be mentioned.

Very important limestone-builders in the past were the Echinoderms, among which the group of *Crinoids* or "sea-lilies" stands out, and the Foraminifera, for the most part small creatures of the size of a pinhead or less, many with the power of secreting a calcareous shell of considerable complexity. Some foraminifera attained larger dimensions, the Nummulities for instance, which derive their name from their resemblance to a coin, formed flat disc-shaped shells of all sizes up to that of a penny and even larger. Limestones full of nummulities were employed in the construction of the pyramids in Egypt.

In different countries different geological systems yield the limestone of commerce. In Great Britain a comparatively small amount is obtained from the Silurian, vast quantities come from Carboniferous limestone and Chalk, and a considerable amount from the Jurassic, much smaller quantities are taken from the Wealden and Purbeck formations and an almost negligible amount from the Tertiary rocks. In France, on the other hand, Tertiary limestone plays a leading part and in the whole of the Mediterranean region they assume great prominence.

Types of Limestone. For practical purposes it is convenient to distinguish certain types of limestone according to their prevalent fossil contents, their texture or structure, or their chemical composition. Some of the more obvious types are mentioned below.

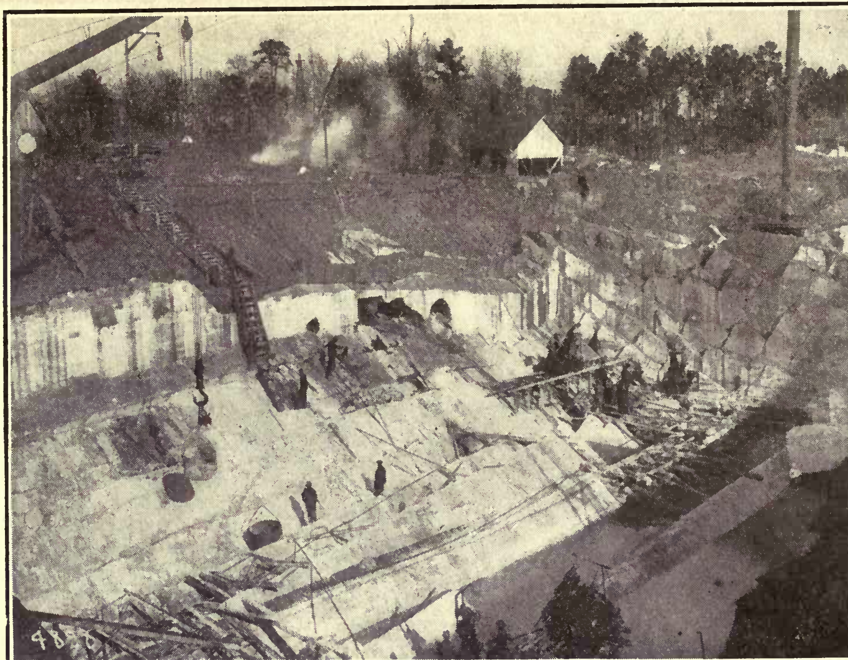


Fig. 5

QUARRY IN OOLITIC BEDFORD STONE, INDIANA, U.S.A.

Note the "Blondin"

Shelly limestones are composed largely of broken and unbroken molluscan shells. If the stone is not well compacted by the growth of secondary calcite the shells may be easily extracted and the stone is of little value for most purposes; but shells may be present in abundance without serious detriment if the stone has become solid and the spaces have been filled.

Coral limestones of recent origin, or from the younger geological formations, are often very hard but full of holes. When the spaces have been filled with calcareous mud and general crystallization of calcate has taken place in the stone it may become dense and solid as in Carboniferous and Devonian limestones.

Crinoidal limestones are composed largely of the hard parts of crinoids, creatures that flourished in great numbers in certain geological epochs. Some of the Derbyshire marbles and the Belgian " petit granit " are excellent examples.

Foraminiferal limestones are built up largely of the shells of foraminifera. These limestones, like others, may be hard and dense or soft, and they occur in all geological ages. Good examples are found among the Carboniferous limestones, which are hard and dense, also in the Chalk which is much softer and lighter. The foraminifera in these rocks are mostly very small, but in the variety known as nummulitic limestone they are much larger.

Oolitic limestones are made up of small concretionary bodies formed of calcite, commonly about the size of the eggs in fish roe, hence the name " roe-stone " sometimes applied to them. These small bodies are spherical or ovoid in shape, and when broken reveal a concentric lamination or radial structure or both, and very frequently there is in the centre a nucleus consisting of a fragment of shell or a grain of mud or sand. Sometimes

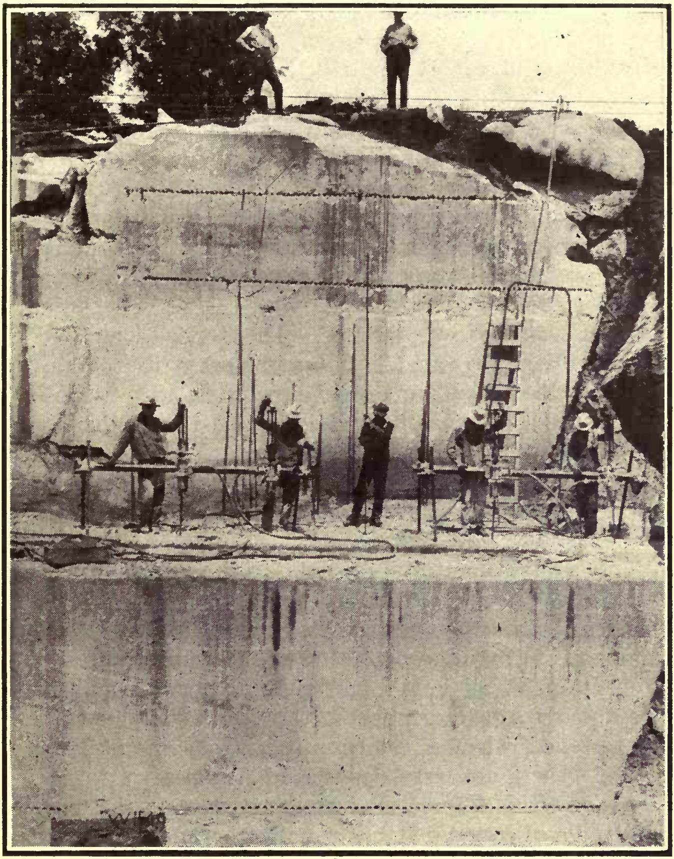


Fig. 6

DRILLING VERTICAL HOLES WITH SULLIVAN QUARRY-BARS

Note the length of the drill-rods and the rows of horizontal holes

the ooliths or oolitic grains are larger, approaching the size of a pea or small bean, when the stone is called a "pisolite."

Oolitic structure is found in limestones of all ages, but in England it is so characteristic of portions of the Jurassic system that the names Great Oolite and Inferior Oolite series have been given to them. In these rocks will be found beautiful examples of oolitic structure, for instance, in Bath stone and Portland stone; but one of the most perfect illustrations is the Ketton stone.

Travertine is a type of limestone formed by some spring waters, heavily charged with carbonate of lime, when they come to the surface. The stone is sometimes very dense and compact, but more often it is highly vesicular, being full of irregular cavities. The deposition of the carbonate of lime is caused partly through the water losing its excess of carbonic acid which enabled it to hold the carbonate of lime in solution, assisted frequently by the action of numerous water-loving plants.

Travertine is naturally restricted in its occurrence though small deposits are not uncommon in limestone districts. Examples are familiar in the dales of Derbyshire and at Knaresborough; but the classical occurrence is in Italy, where it is found in thick deposits and has been quarried for centuries, in the vicinity of the Tibur for instance, whence it derives its other name of Tibur stone. There are large deposits in America.

Stalagmite is formed in a similar way upon the floors and walls of caverns. It is usually thoroughly crystalline and exhibits when broken across a wavy banded structure, representing layers of accumulation. It is employed for ornamental purposes.

Marl, according to the usage of geologists, is a soft argillaceous limestone which may pass by increase of

its clay content into a calcareous clay. The Chalk Marl may be taken as a fair example. But since the name is used in several different senses, caution is necessary when employing it. Thus, in Staffordshire and some other parts of England "marl" is a rather hard, unbedded non-calcareous clay, employed for making bricks and "saggers." In many parts of England it used to be a common practice to quarry any local argillaceous material for "marling" or spreading on the land to improve its agricultural properties. Again, in the United States the bog-limes are often called marls.

Lake or bog limes are deposits of carbonate of lime formed in freshwater pools and lakes, mainly from the debris of shells and lime-secreting water plants. Such deposits yield a very pure carbonate of lime, but the material cannot be called stone since it is always in a soft condition or even in the state of a slurry. Bog-limes have been used for preparing cement.

Magnesian limestones contain more or less magnesium carbonate $MgCO_3$ in addition to lime carbonate. Stones with more than 5 per cent. of $MgCO_3$ are classed as magnesian limestones. The magnesium carbonate is usually combined with calcium carbonate in the form of the mineral dolomite $CaMg(CO_3)_2$, which crystallizes in small rhombohedra. These crystals may be scattered sparsely through the limestone or may make up the bulk of the rock, in which case the rock itself may be called a dolomite. These limestones may be any colour but they may be distinguished from pure calcium carbonate limestones by their slower effervescence when treated with cold dilute acid.

They occur in all the geological systems but in England they are found most prominently in the Permian Magnesian Limestone formation, which extends from

the borders of Derbyshire and Nottinghamshire northwards to the coast at Sunderland. It is quarried at many places on the outcrop for building stone, lime and steel-hearth dolomite. Magnesian limestones are common in the Carboniferous system, though good dolomite is more restricted.

CHAPTER V

SANDSTONES

General Characters. Rocks of this class are composed of consolidated sand, they consist therefore of separate grains of mineral or rock united by some form of cementing or binding material.

The grains make up the bulk of the stone, the most common grain mineral is quartz, and this may be regarded as typical of all normal sandstones. Other mineral grains are usually present in varying degrees of abundance, of these the more important are the felspars and micas. If grains of felspar form an important part of the aggregate the stone is described as a felspathic sandstone, if there is much mica it is a micaceous sandstone; the bulk of the mica in sandstones is of the muscovite variety. Other mineral grains occur, but more irregularly and locally, and from the practical standpoint they are quite subordinate in importance.

The mineral grains composing a sandstone may be angular, subangular, or rounded, and their dimensions may range from almost microscopic particles to grains of the size of a pea. Moreover, the ratio of grains of different sizes may vary considerably. The size and angularity of the grains is a matter of importance in some of the industrial uses of sandstone. When the grains are large the stone is often called a "grit," but the term is sometimes applied to finer-grained stones in which the particles are sharp and angular.

The binding or cementing material almost universally present is silica, usually described as "secondary" silica to distinguish it from the original quartz grains. This cementing silica results from the decomposition

of felspars or from the partial solution of the original quartz, or it may have been introduced into a mass of sand by subterranean waters from other rocks. The secondary silica is usually found in the form of quartz, which may have grown in crystalline continuity with the original grains so as to complete or tend to complete their crystal form, or it may have formed new independent grains between the older ones. Sometimes the binding silica is in the condition of chalcedony or opal.

The binding material may also be calcite, dolomite, iron oxides, clay, bitumen, producing respectively calcareous, dolomitic, ferruginous, argillaceous and bituminous sandstones. This list does not by any means exhaust the varieties of binding material, there are others, for instance, which make some sandstones of great value as *ores* of metals, but those binders mentioned above are the chief ones from the standpoint of stone.

It is not to be supposed that the binding material is always simple, thus a calcareous and ferruginous bond may be present in the same stone; usually, however, one or other kind predominates, though a certain amount of siliceous cementation is nearly always in operation.

Clearly the nature of the bond that holds together the grains of sand, the relative amount of it, and the presence or absence of empty spaces between the grains are matters of the first importance in the industrial application of sandstones and their significance in particular cases will depend upon the use to which the stones is applied.

The *colour* of sandstones is largely determined by the bonding and inter-granular material. If the sand grains are of clean quartz and they are united by a siliceous cement the colour of the stone is white. A

sparkling appearance is caused by tiny faces on the quartz grains if they have developed crystal outlines through secondary growth. A whiteness of greater opacity is frequently induced by the presence of kaolinic material resulting from the breaking down of felspar grains. Numerous mica plates will also produce a glistening and whitish appearance. Various shades of red, brown and yellow are caused by oxides of iron, which may exist within the grains of quartz, or as a film on their surfaces, or as a component part of the infilling, finer matter between the grains. Some sandstones have a greenish tint caused by the presence of small green grains of the mineral glauconite, such are some of the Greensand stones, though they are more often brownish and yellow through the oxidation of the iron. Shades of grey to black may be due to carbonaceous interstitial matter, sometimes to the presence of shale and other dark rock fragments among the grains, as in many of the older sandstones. A bluish or greenish grey tint is caused by finely divided iron sulphide; in this case the stone tends to weather brown.

Origin—Mode of Occurrence. Sandstones are detrital deposits formed from the more resistant products of the destruction of older rocks, granites, gneisses, sandstones, etc. These materials have been sorted and deposited by the waters of rivers or along shore-lines, or, in some cases, by the action of wind.

As a consequence of their mode of formation sandstones occur in beds, sometimes thin and flaggy or shaly with films of mica grains, or layers of shale or clay between them ; or they may form thick and massive beds extending over areas of hundreds of square miles. These thicker beds often show secondary bedding planes running diagonally between the main bedding planes; since they are due to the action of currents at the time

of their deposition the structure is called "current" bedding, it is the same as "false," "diagonal," or "cross" bedding. Ripple marks and footprints are not uncommon upon the surfaces of bedding planes. Indications of vegetation are frequent in some sandstones but other fossils are comparatively rare.

Sandstones are sometimes marred for industrial purposes by local variations in the nature of the cementing material, hard and soft parts occur; variations in the character of the sediment may give rise to conglomeratic or pebbly patches, or to lenticles of shale and "galls" of clay. Irregular staining owing to the segregation of iron oxides is another common defect in sandstones.

Geological Age. Sandstones are found in strata of every geological system, but the formations that carry good sandstones in one region do not always do so in another. In Great Britain the older sandstones and grits, in the Cambrian, Ordovician and Silurian systems are rather dull and dark in appearance and are often difficult to work. The Old Red Sandstone yields good flagstones and some building stones; but the great reserve of sandstone is found in the Carboniferous system, including the Millstone Grit, the Yoredale series and the Coal Measures and their equivalents. The Permian system produces a few well-known sandstones, and the Trias many, of which the majority are red but some are yellow or cream coloured. The Jurassic sandstones are unimportant except for local use, and a few are found and employed in the Wealden area from the Lower Cretaceous rocks. The Tertiary sandstones are insignificant though a few have been used on a small scale.

Special Types—Quartzite, Gaize. One or two varieties of sandstone require special notice, of these quartzite

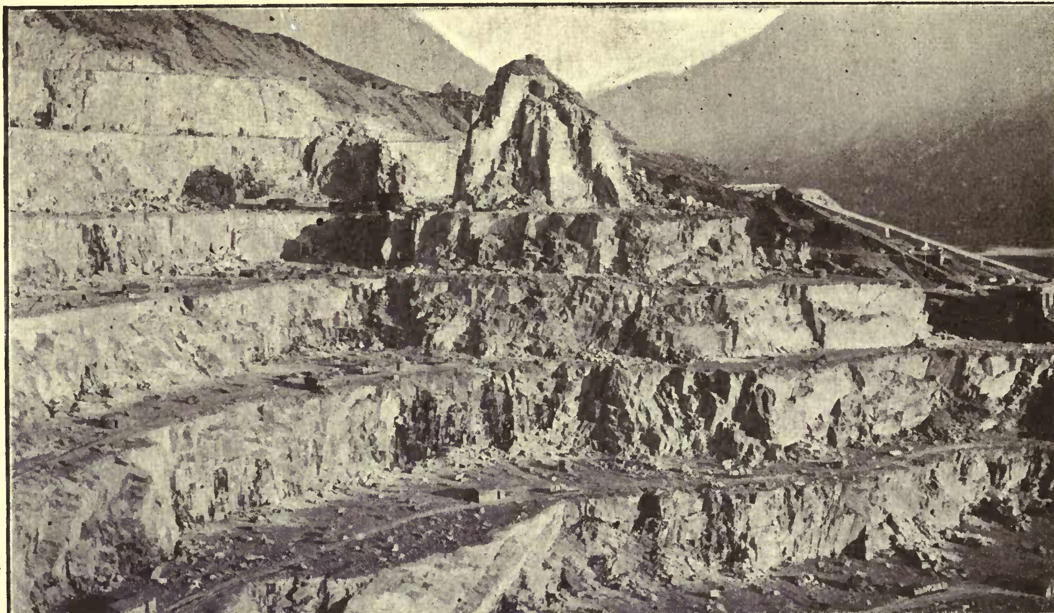


Fig. 7

PORTION OF THE GREAT SLATE QUARRY, DINORWIC, N. WALES, SHOWING TERRACES

is the most important. A true quartzite resembles sandstones of the ordinary kind in that it once consisted of separate sand grains, but it differs from them in being harder and denser and in having the grains so thoroughly united that the stone, when fractured, is broken through instead of round the grains, as is the case of the majority of sandstones. In quartzites the grains are welded together by the action of earth pressure or heat, or both, and there is no binding medium other than silica.

Since quartzites are produced by metamorphic agencies they are most abundant in the older formations, for instance, the quartzites of the Licky Hills in Worcestershire are of Cambrian age; they are employed for road metal.

Sandstones and grits occasionally take on some of the characters of quartzites through extensive secondary silicification; a stone of this character is *ganister*, a hard fine-grained siliceous sandstone found mainly in the Lower Coal Measures of Yorkshire, Derbyshire, and Lancashire, which is of great value in the manufacture of silica-bricks.

Gaize. A very different type of stone, often called "malmstone" in England and "gaize" in France, is a soft stone of pale colour, usually calcareous and often slightly argillaceous, containing a certain amount of very fine quartz sand grains and a large amount of opaline silica in the form of small granules and sponge spicules.

Other Fragmentary Stones. Although obviously different from sandstones, these other stones may be mentioned here because they, too, are made up of the detritus of pre-existing rocks. *Conglomerate* is a rock made of rounded pebbles or boulders held together by one of the usual binding materials. If the pebbles are

loose they constitute *gravel* or *shingle* when the individuals are small or *boulders* when they are large. When angular fragments are cemented into a solid mass the rock is called *breccia*. The stones in gravel are commonly subangular.

CHAPTER VI

SLATE

General Characters. The outstanding quality of slate is its capability of being split or cleft into thin sheets of great strength relatively to their thickness. Other rocks, shales for example, may be split parallel to their bedding with remarkable ease, but the flakes so produced are comparatively small and are always weak. Slate is sometimes cleavable parallel to the bedding but rarely, more often the direction of easy cleavage lies at a high angle to the original bedding.

Typical slate has a fine close texture and is composed of a felted mass of minute mineral flakes having irregular outlines, these are arranged so that their greatest lengths are in the same direction, with their flat faces approximately parallel to the plane along which the stone most readily cleaves.

The minerals that form the bulk of slate are quartz, sericitic mica and chlorite; other minerals often present are felspar, biotite, magnetite, haematite, limonite, pyrite, carbonates of lime, iron and magnesia, epidote, andalusite, rutile, graphite or carbonaceous matter and numerous other accessory minerals.

Dark grey and blue-grey slates owe their colour to iron compounds or carbonaceous matter; red and purple slates contain minute specs of haematite; a green tint is usually due to chlorite, sometimes to epidote. Some slates are dull, others have a shining lustre, generally due to a large development of mica on the cleavage faces. The cleavage face may be smooth and even or covered with small lumps often due to small crystals of

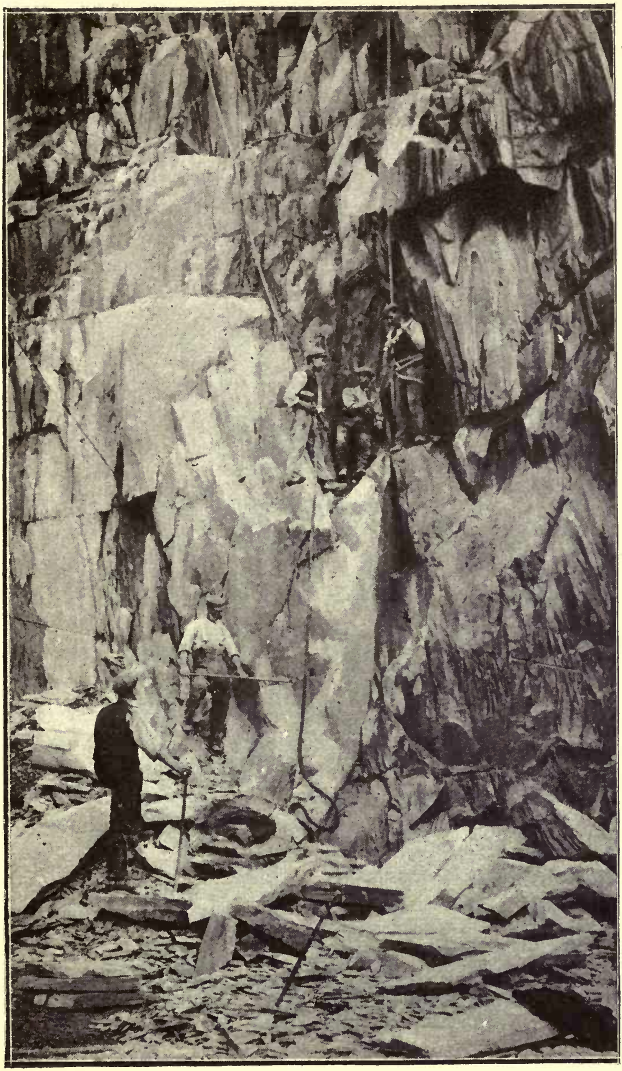


Fig. 8

QUARRYING SLATE, DINORWIC

Part of one of the terrace faces

magnetite or pyrite. The faces of slates are frequently crossed by straight or crumpled bands of a slightly different colour, this is the " stripe " or " ribbon " and is due to the trace of the original bedding.

Besides splitting along the principal direction of cleavage slates show a tendency to fracture, though less easily along other directions which, like the main cleavage, are fairly constant in any one region. They are of importance, for if these tendencies are unduly developed they may impair the utility of the stone. One of the secondary cleavages usually runs more or less parallel to the dip of the main cleavage but at right angles to it, this is the " grain " of the slate, a special term not to be confused with coarseness or fineness of grain. The " sides " of a block of slate are parallel to the " grain." One of the results of the pressure that has produced the main cleavage in slates is the formation of incipient " shear planes " which lie approximately at angles of 45° to the main cleavage. These are planes of weakness, and if highly developed they cause the slate to split too readily in the wrong directions; they are known as " false cleavage," " strain-slip-cleavage," " close-joint cleavage," or to the Welsh workers as " gwniad," to the Americans as " bate," and to the slate merchants as " lace."

Origin of Slate. Slate is a product of the alteration fine-grained argillaceous rocks, such as shales, clays, of mudstones among the sedimentary rocks and occasionally of ashes and tuffs among volcanic rocks.

Slate is thus caused by one of the phases of metamorphism. It is always found in regions where the rocks as a whole have suffered movement and deformation; it is not found in undisturbed strata. In such regions the rocks have been much crumpled and folded, and have been subjected to great pressure in the process.

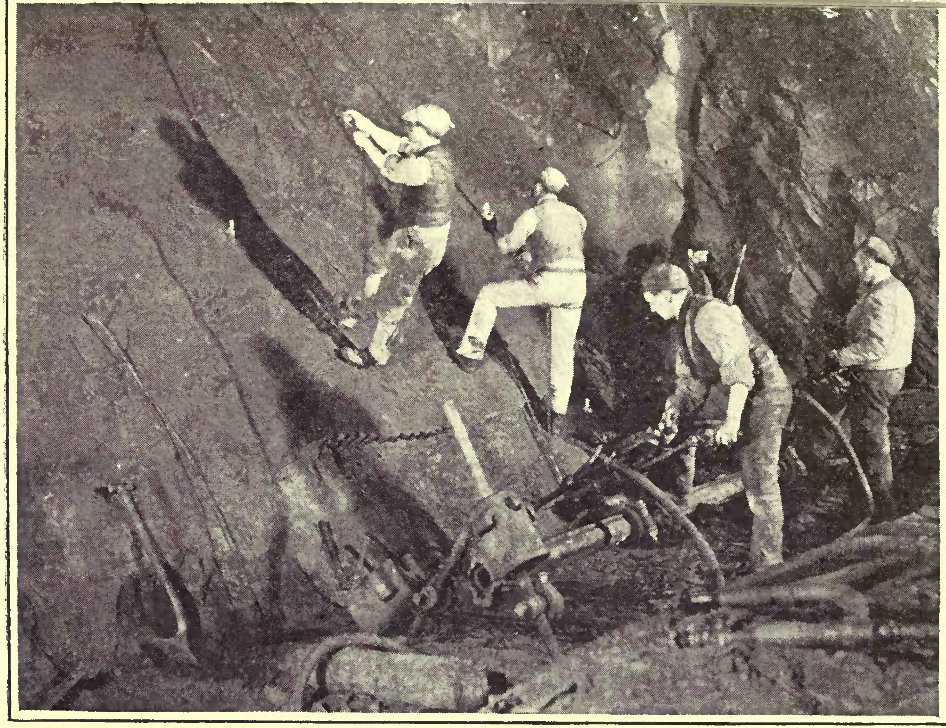


Fig. 9

CHANNELLING A FOOT-JOINT IN SLATE WITH QUARRY-BAR AND COMPRESSED AIR DRILL

The stresses to which shales and the like have thus been subjected have produced in them a rearrangement of the minerals together with re-growth, and a definite orientation of the particles so that their larger axes have been placed normal to the direction of pressure. This is the cause of the fixed direction of cleavability in masses of slate over large areas and the complete or partial disappearance of the original bedding at the same time.

Geological Age. Slate is a common rock, but owing to the difficulty of finding good *workable* stone first-class material is relatively rare. Except in the younger mountain regions it is most abundant in the older formations. In Wales it is obtained from the Cambrian, Ordovician, and Silurian systems. The green slates of the Lake District are of Ordovician age, but differ from those of Wales in that they are composed of volcanic material. The dark slates of North Cornwall are of Upper Devonian age; in Scotland the Highland Metamorphic series yield most of the slate.

CHAPTER VII

MARBLE

Marble. As understood by geologists marble is a calcareous or magnesian limestone in a thoroughly crystalline condition; commercially the term includes other kinds of stone if they are capable of taking a polish and can be used for decorative purposes; granites and other familiar igneous rocks are not here included. The majority of commercial marbles are also marbles in the stricter sense.

The crystalline condition of true marbles is the result of metamorphism, and they are commonly associated with other rocks of this class. The effect of metamorphism on limestones is to induce crystallization in hitherto uncrystallized portions and a re-crystallization and adjustment of existing crystals; this is accompanied by the obliteration of bedding, fossils, and most of the original structures. Thus an oolite or a shelly limestone, or a chalk-like rock may be converted into a compact crystalline marble by earth pressures, leaving no trace of oolite grains, shells, or chalky characters.

The degree of alteration varies widely; some marbles have been subjected to the most violent squeezing and contortion as may be seen by the form taken by streaks in the marble, and better by the evidence of adjacent rocks of other kinds, for limestones show a remarkable mobility under pressure, owing to the perfect cleavages in the calcite grains and their capacity for re-adjustment, and as a result the surrounding rocks may be strongly sheared and foliated while the marble takes the form of a compact and massive body. On the other hand limestones frequently develop a sufficiently crystalline

structure to enable them to pass as marbles by internal changes developed without excessive pressures and their accompaniments, and such marbles could not be classed as metamorphic rocks, and they do not possess the perfect crystalline granular structure of the best marble; examples of this type are to be found in the Carboniferous limestones of England and Ireland.

The crystalline grains of calcite or dolomite in marbles are occasionally quite coarse, easily visible to the unaided eye, but these marbles are not so generally useful as those of finer grain. Stones that are not sufficiently crystalline lack the translucency which gives the peculiar charm to the surface of good marble.

Marble, whether employed in construction or in applied decoration, is valued according to its beauty or rarity. The beauty of marbles depends mainly upon their colour and their "figure," by which is meant their characteristic marking or mode of distribution of the colours.

As regards colour, this may be uniform throughout the stone, giving what is called "self-coloured" marbles, which may be pure white, black, or some shade of grey, yellow, brown, red, green, etc.; on the other hand the general effect of one of these colours may be produced by blotching, streaking and shading of a mixture of tints combined in an infinite variety of ways.

The "figure" or pattern of marbles is capable of a rough classification somewhat on the following lines—

(*a*) Mottled, Blotched or Clouded. In its simplest form this type of pattern is due to the irregular distribution of pigment either in soft-edged, cloudy patches or blotches with sharper outlines.

(*b*) Banded. The colour changes occur in bands, straight or wavy. When the banding is wavy quite intricate patterns can be developed in these marbles by

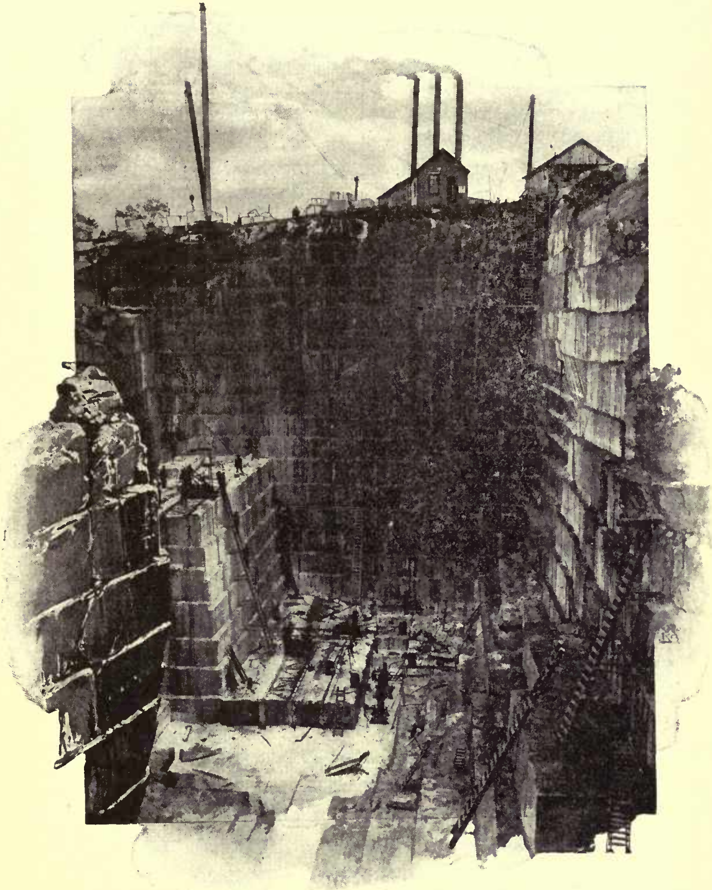


Fig. 10

QUARRY OF THE SOUTH DOWN MARBLE CO., U.S.A.

cutting them parallel or nearly parallel to their general direction; for instance in the green cippolino or brown rosewood marbles.

(*c*) Streaked. This pattern, in which irregular and ill-defined streaks of one or more tints cross a stone of some other colour, is most commonly met with in the white-ground marbles of metamorphic origin.

(*d*) Veined. This is a very common type of pattern produced by definite veins with sharp outlines, usually zig-zag or irregular in direction, crossing a flat tint of another colour. They are caused by the infilling of cracks, or of solution cavities formed in the stone at some stage of its history. They are found in the less altered rocks and in the highly metamorphosed ones.

(*e*) Brecciated. Marbles presenting the appearance of being made of angular fragments of the same or of different kinds of stone have been formed by the natural cementation of rocks which have either been broken in the neighbourhood of a " fault " or " thrust " caused by earth movements or they may have accumulated at some time as the result of subaerial weathering. Some of the breccia marbles have very striking pattern; examples of the first kind are Brèche violet, Breccia di Verona.

(*f*) Figure due to Fossils. This type of pattern is naturally found only in those marbles that have not undergone extensive metamorphism. The fossils may be of various kinds, molluscan shells, crinoids, corals, etc. Examples with shells are Purbeck marble, full of Paludina shells and lumachelle, composed of shells of various kinds. Crinoids form the pattern in the grey " dog tooth " marble of the Carboniferous rocks of Derbyshire, Yorkshire, Somerset and Ireland, and the " petit granit " of Belgium. Corals are the cause of the figure in the black Frosterley marble and the " Bird's

Eye" marble of Derbyshire, the "Stag's Horn" or "Madrepore," and other marbles of Devonshire.

Besides the true marbles and the partially marmorized limestones, there are several other kinds of stone commercially classed as marbles, employed for the same purposes; such are the so-called *Onyx marbles, Serpentines, Alabaster, Sodalite, Lapis-lazuli, Verdite Malachite* and many others.

The *Onyx marbles*, like true marbles, are calcareous rocks, containing usually well over 90 per cent. of carbonate of lime; they have either a crystalline granular or fibrous texture; they are translucent to opaque and the colour ranges from a milky white through shades of yellow, red, green, or bluish to almost black. It is characteristic of most onyx marbles to exhibit a banded structure, a fact which doubtless caused the name onyx—strictly applicable only to the siliceous banded stone (p. 9)—to be misapplied to them.

Onyx marbles are formed by the deposition of carbonate of lime by hot springs in regions of volcanicity or by cold waters percolating through the roof and walls of caverns. In each case the deposit is formed by the accretion of layer upon layer followed by crystallization in the deposited mass. When formed on the walls or floors of caves the material is known as *stalagmite*, deposits hanging freely from the roof are *stalactites*. The name *oriental alabaster* is sometimes given to stone of this kind. The finest quality of onyx marble is that formed by hot springs. As a natural result of their mode of occurrence the onyx marbles have a much more restricted distribution than ordinary marbles, and they can rarely be obtained in large amounts or in very massive blocks. Frequently the sound, dense slabs of the stone are separated by travertine of a more porous and crumbly nature which is useless.

The best known sources of onyx marble are—

Algeria, in the province of Oran on the right of the Isser. Egypt, at Beni Souef and Syout, both in the Nile valley. Mexico and Lower California. Arizona in Yavapai county, and several other centres.

California, Virginia, Colorado, Utah, New Mexico, where cave deposits provide most of the material.

The *Serpentines* are rocks composed mainly of the mineral serpentine (p. 13), they thus differ markedly from the true marbles in composition, since they are formed principally of hydrous silicate of magnesia. They are usually the result of the alteration of basic igneous rocks, especially those rich in olivine and pyroxenes. During the process of alteration other minerals are formed including iron oxides, often in considerable amount, iron pyrites, chromite, calcite, dolomite, magnesite, steatite. Remnants and cores of the original olivine or pyroxene are often present. It is largely on account of the presence of these minerals, occurring in veins and irregular blotches that the serpentines show such rich and varied colouring.

The name Serpentine is derived from the serpent-like colour and mottling of the stone; the colours range from pale translucent greens to dark greens, and dark browns, variegated with innumerable types of spotting, mottling, and veining. Some paler varieties, green with white calcite or dolomite streaks, spots or veins have been called *ophite* or *ophicalcite*. The name *verd antique* (vert antique, verde antico) has been given to some of the darker varieties, such as were popular with the ancient Romans. Some of the so-called verd antique marbles are strongly brecciated.

The serpentines are soft stones and very subject to flaws and shakes and it is rarely possible to secure large sound blocks.

In Britain serpentine is best developed in the Lizard district of Cornwall and in County Galway, Ireland. The Cornish serpentine exhibits a wonderful variety of rich colouration in shades of green, brown and red, a fine series of examples may be seen in the Museum of Practical Geology. The Galway serpentine, ophicalcite or "Connemara green" is of a brighter green or mingled pale and dark greens with white. A small amount of rich dark green serpentine has been quarried occasionally in Anglesey.

Serpentine has been worked in Pennsylvania, Maryland, Massachusetts, Michigan, New York, Vermont, California, Washington, and is known to occur in other parts of the United States. In Italy serpentines have long been quarried, they include the brecciated *Verde di Genova*, *Verde di Levante*, *Verde di Pegli*, and the *Verde di Prato*.

Alabaster is the massive, granular form of gypsum (p. 14) capable of taking a polish. In colour it is white, yellow, reddish, green or grey, and is often streaked or clouded with these tints. Compared with marble it is very soft and readily scratched. For internal decoration, when it is not subject to abrasion, it is used with excellent effect, and it is employed on a considerable scale in making small ornaments. It is obtained at Fauld in Staffordshire and Chellaston in Derbyshire. In Italy it is found in Tuscany and Piedmont where a large trade is done in small vases, etc., often elaborately carved. Its pure white variety is employed for statuettes, which, after carving, are made opaque to resemble marble by heating gradually in hot water. Alabaster is also worked in Spain. "Oriental Alabaster" is the name sometimes applied to the stalagmite marbles.

Verdite is a very beautiful green stone, from near Barberton in South Africa, composed largely of talcose minerals.

CHAPTER VIII

GRANITES

General Characters. The granites are granular-crystalline rocks typically composed of the minerals quartz, felspar, and mica. Occasionally mica may be absent. The felspar most prevalent is orthoclase but other varieties occur, including microcline, albite, alkali felspars, and soda-lime felspars. Both muscovite and biotite mica appear in granites, they are sometimes replaced or accompanied by hornblende, augite, enstatite and tourmaline.

These minerals are normally distributed evenly throughout the mass in grains of approximately the same size but the felspars are usually the most obvious. If the felspars average over $\frac{2}{5}$ in. the stone would be considered coarse, if $\frac{1}{5}$ in. the stone would be of medium grain, if smaller it would be fine grained.

In some granites there is a dissimilarity in the felspars, some appear much larger and better formed than the rest, these are porphyritic crystals, formed somewhat earlier than the others, the stone containing them is called porphyritic granite. There may be two crops of such crystals, one with larger individuals and another with smaller ones. To be noticeable they must be over $\frac{1}{4}$ in. in length, but they reach as much as 6 in. in some stones. Good examples are the Colcerrow and Lamorna granites of Cornwall with large grey felspars, and the Shap granite with reddish porphyritic felspars about 1 in. in length.

The colour of granites is determined mainly by that of the felspars which may be a pearly white, dull white, pale grey or dark grey yellowish and pink to red. The

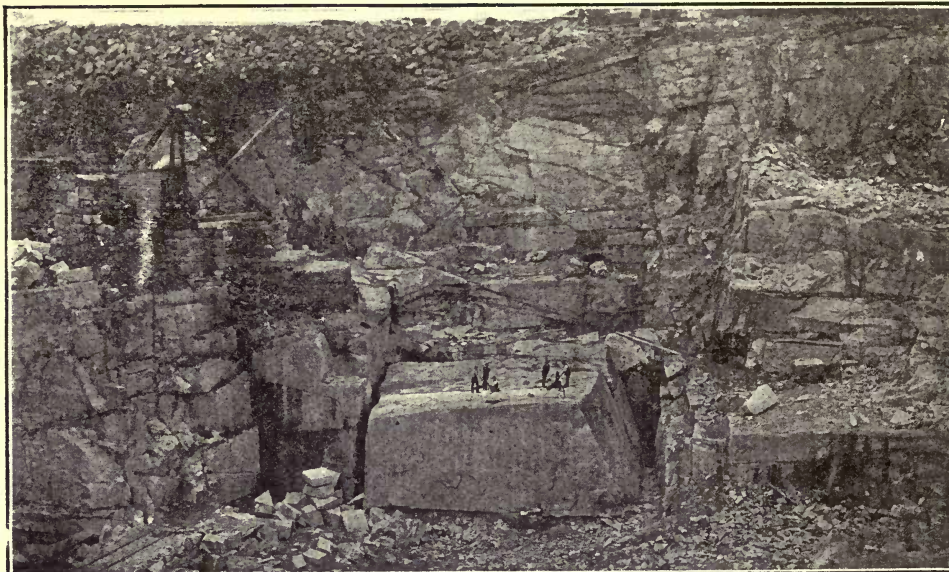


Fig 11

LARGE BLOCK OF GRANITE, WEIGHING ABOUT 2738 TONS

Quarried by Messrs. Freeman at Polkanuggo, near Penryn

general colour effect is modified by the amount and kind of mica and the dark minerals, hornblende, etc., when present. In some granites the quartz, which is usually colourless, is tinged with blue.

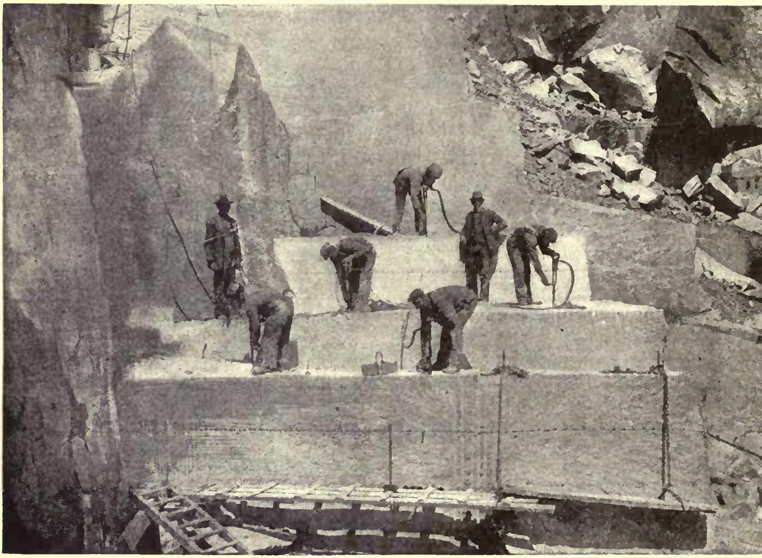


Fig. 12

DRILLING PLUG AND FEATHER HOLES FOR SPLITTING GRANITE

Rockport, Mass., U.S.A.

Granites are described for trade purposes by the colour and size of the grain, thus one speaks of a coarse grained grey granite or a medium-grained red granite, and so on. They are sometimes classed according to their special suitability for specific purposes, as constructional- monumental- or decorative-granite. They

may also be described in accordance with their characteristic mineral contents as muscovite and biotite granites, or when both micas are well represented as muscovite-biotite granites, also as hornblende-, augite-, or tourmaline-granites, if one or other of these minerals is conspicuous.

Mode of Occurrence. Granites are typical plutonic igneous rocks that have solidified deep in the earth under great pressure. They are thus to be found only when the strata under which they formed have been removed by the processes of denudation. Granites have been solidified as large irregular masses or smaller lenticular masses and bosses, also in the form of veins crossing other rocks at a high angle or as " sills " thrust in between beds of other rocks; but the majority of workable granites are found in the larger masses. On the outer edges of such masses and often forming veins and narrow offshoots from them, the granite is apt to assume a much coarser grain, to which the name "pegmatite" is given. These pegmatites are often of economic importance for the coarseness of the individual minerals quartz or felspar or mica enables one or other of them to be selected with comparative ease; consequently they are the source of picked felspars for use in pottery and glazes and of mica for use in electrical instruments and a number of other purposes; the quartz may also be picked out for use as silica. Other rarer minerals of value are also found as accessory minerals in pegmatites. A structure frequently found in these rocks resembles Hebrew script and hence has given rise to the name " graphic granite "; the stone is used in making small ornamental objects.

Veins of finer or coarser granite often traverse the main mass, and if numerous they depreciate its value by making the extraction of marketable stone more

difficult. Some granites are disfigured by the too frequent occurrence of clots, knots, or segregations of mica or other dark mineral or by inclusions of the surrounding rock.

Fortunately granite is one of the most tractable of the igneous rocks to quarry. Like other rocks it is traversed by vertical or slightly inclined joints which, if not too closely set, assist in the extraction of the stone. Granites often possess also another set of divisional planes which break up the mass into large lenticular slabs; since this feature produces a resemblance to the ordinary bedding of sedimentary rocks it has been called pseudo-bedding or sheeted structure. The sheet planes run approximately parallel to the surfaces of the mass, and they are of the greatest assistance to the quarryman. As a rule the deeper a quarry enters into the mass of granite the thicker the sheets become.

In addition to the well-marked planes of separation granites are generally much more readily split in one direction than another. The direction of easy splitting is called the " rift," this is most often more or less parallel to the sheet surfaces, but not always so, it may be constant in direction throughout a large mass of granite or it may vary from point to point in the same quarry, or even from sheet to sheet. In some granites the rift works more easily when the split is made from one side of the block; if it is made from the adjacent sides it may tend to curl upwards or downwards instead of passing straight through; this deviation from the straight direction is called the " run " of the rift. In another direction, usually at right angles to the rift, the granite can be split, but less easily; this is called the " grain " of the stone, which it must be noted is quarryman's grain and has nothing to do with the granular texture.

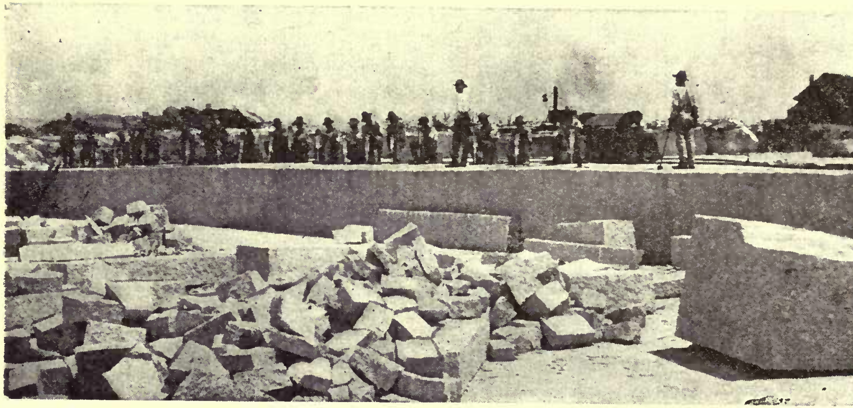


Fig. 13

SQUAD WORKING SULLIVAN PLUG DRILLS

N. Carolina Granite Corporation, Mount Airy, U.S.A.

Finally, in the remaining space direction the granite usually splits badly, this is the "hard," "hard way," "cut off," "tough way" or "quartering way" of different quarry districts. In this direction the stone has to be channelled or broken off.

The *specific gravity* of granite is from 2·6 to 2·8.

The *weight* is 160 to 200 lb. per cubic foot or roughly 2 long tons per cubic yard.

The *crushing strength* is 15,000 to 40,000 lb. per square inch or, say, 1,000 to 2,200 tons per square foot.

The *absorption* and *porosity* are low, usually less than 1 per cent. in good stone.

The resistance to *weathering* is high in all good stone, that is, if it has not been badly weathered and stained previously, and if it is not suffering from the presence of small cracks. The finer and medium grained granites are on the whole better than the coarse and strongly porphyritic varieties.

The resistance to *fire* is poor; under the influence of great heat followed by quenching granite spalls badly and crumbles away. A good example of the effect of fire may be seen in the damage recently caused to the plinth of Nelson's Monument in Trafalgar Square.

Other stones which, because of their similar texture and mode of occurrence, may be considered with the granites are, Syenite, Diorite, Gabbro, and some forms of Gneiss.

Syenites resemble granites in chemical composition, but they contain less silica. They are normally composed of orthoclase felspar, and hornblende, which may be replaced respectively by the felspathoid elaeolite and mica or augite. Quartz is normally absent. They are less common than granites but may be used for the same purposes with good results. Their specific gravity is slightly higher than the granites, and their crushing

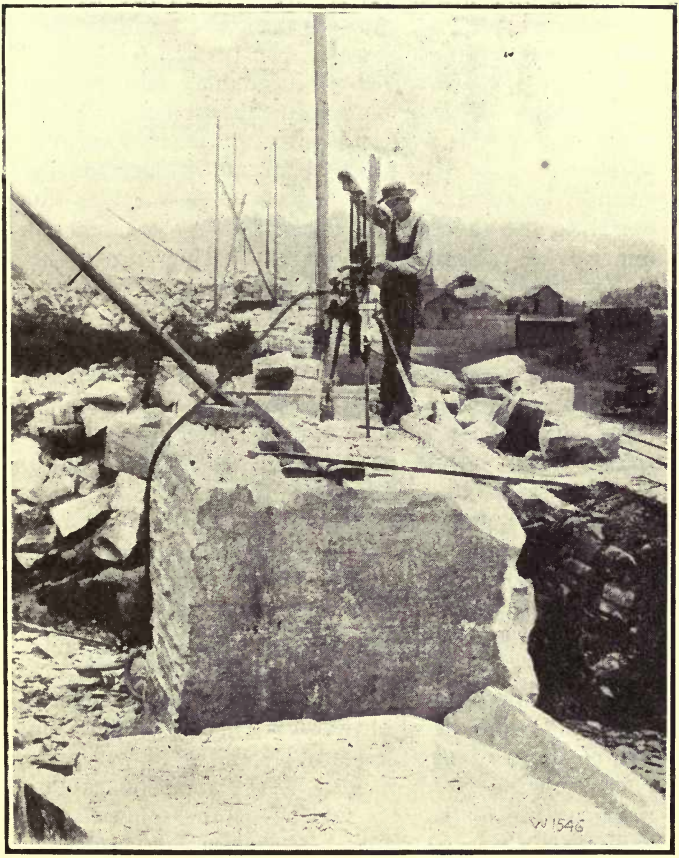


Fig. 14

SULLIVAN HAND-HAMMER DRILL SUPPORTED ON TRIPOD FOR BREAKING UP A BLOCK OF STONE

strength is about the same. No true syenites are worked in Great Britain, though some of the Leicestershire road stones approach the type.

Diorites are composed of soda-lime felspars and hornblende; quartz is not normally present. Biotite and some of the pyroxenes are not uncommon constituents. They are usually darker in colour than the granites or syenites, often with a greenish tinge due partly to the alteration of the original ferro-magnesian minerals to chlorite and epidote. They are rather heavier than the granites and are somewhat less hard and resistant to pressure.

Both syenites and diorites grade into true granite by the addition of quartz and other mineral changes. Diorites are less common than granites; they occur in the Channel Islands, near Mount Sorrel in Leicestershire, in the Southern Uplands and Highlands of Scotland, and in South-Eastern Ireland.

Gabbros, though possessing the coarse or medium granitic texture, differ from granites in several ways. They normally contain no quartz, the total silica content is 52 per cent. or less and the typical minerals are lime-soda, felspar, and augite, and the colour is always dark. As a group they present many varieties of mineral composition differing more or less from this type, thus other forms of pyroxene, biotite, olivine, and hornblende may take the place of some or all the augite. A characteristic form of much of the augite in gabbros is known as diallage, a variety of the mineral that exhibits a play of colour or irridescence on broken or polished surfaces, which sometimes makes the stone very effective in polished slabs.

Gabbros are subject to a good deal of local variation in the mineral composition, patches being formed wholly of felspar, others of diallage, olivine, etc. They

are heavier than granites; specific gravity, 2·7 to 3; their crushing resistance is about the same.

In Great Britain gabbros occur in the Lizard district, Cornwall, St. David's Head, and the Lleyn peninsula in Wales and at Carrock Fell; in Skye and Ayrshire, and at many places in the Highlands of Scotland; in Guernsey and at Carlingford in Ireland.

Gneisses, when granitic in composition and not too strongly foliated, are frequently employed in the same way as granite.

CHAPTER IX

OTHER IGNEOUS ROCKS

In dealing with the igneous rocks, other than granite, from the commercial standpoint, since it is not possible to follow at all closely the finer distinctions of the petrologist, a rough and ready sort of classification has to be adopted. In the first place in all the types of stone now to be discussed the general texture is finer than in the granite group, the granular texture of granite is present in a few of them but on a much smaller scale, and although there are many very different kinds of texture among them this is not readily, if at all, discernible by the naked eye.

A simple method of grouping these rocks is to arrange them in the following classes: (1) The paler finer-grained rocks; (2) the darker finer-grained rocks; (3) porphyritic rocks ; (4) vesicular rocks, and (5) fragmental rocks; it being understood that this rough classification is not a scientific one.

(1) *Paler finer-grained rocks.* This group includes some members with the fine granitic texture, sometimes described as *micro-granites*; many of the *elvans* or dyke rocks of Cornwall would fall into this class. A rock of granitic composition but with a peculiar texture caused by the simultaneous crystallization of the quartz and felspar bears the name *granophyre*. A similar texture on a larger scale is exhibited by graphic granite (p. 51).

The type of texture most common in this group is that produced by a sort of fine feltwork of small elongated crystals of felspar with quartz in the interspaces. This kind of texture varies in its degrees of fineness but

Fig. 15

A SULLIVAN DRILL OPERATING HORIZONTALLY

except in the vesicular forms described below, it results in a smooth-grained compact kind of stone. *Felsite* is the general name for rocks of this kind. Very similar in many respects are the *Rhyolites*, volcanic rocks in which flow structure, banding and spherulitic structure are common, together with the presence of more or less uncrystallized rock glass. When the stone is mainly composed of glass we have *Obsidian*. If the glass has become devitrefied, just as artificial glass may be changed in time, the rock passes over into a felsite. The rhyolites correspond with the granites in composition. Another closely related volcanic rock is *Trachyte*, its texture is similar to that of the rhyolites but it is usually more crystalline, though essentially of the felsitic type, in composition it corresponds to the syenites, consequently quartz is less abundant than in the rhyolites. The rocks of this group occur in the form of dykes, sheets and flows.

2. *Darker finer-grained rocks*. One of the best known rocks of this group is *Basalt*, which is typically a dark grey, almost black stone with a greenish tinge, weathering to a brown colour. It may be very dense and compact or vesicular; it is heavier than rocks in the first class, having a specific gravity of 2·8 to 3·3. In texture it is not unlike a coarse kind of felsite, but the felspars forming the bulk of the ground mass are larger and often described as lath-shaped, they are not visible without the use of a magnifying glass or microscope. In some basalts a fair amount of glass is present. When the texture is coarser basalt passes into the form known as *Dolerite*, a stone that is also "basalt" for commercial purposes. Both basalt and dolerite often contain the mineral olivine, and in the latter augite is characteristic. The crushing strength of basaltic rocks is high, from 2,000 to 3,000 tons per square foot and occasionally

much higher; they are very tough. The conductivity to heat is rather high and the absorption is about 1 per cent. In composition the basalts resemble the gabbros.

Andesites are volcanic rocks resembling the trachytes in some respects but with more lime-bearing felspar, and darker in colour; they are not, however, so dark or so heavy as the basalts. Hornblende and biotite are the most common dark minerals, but a light green augite is often present. There may be some unresolved glassy matter in the rock and flow structure may be exhibited. The andesites are neither so strong nor so tough as the basalts.

A columnar jointing is common in the basalts, as exhibited in the Giant's Causeway and in Fingal's Cave, Staffa. This, when present, makes the quarrying easy, but when it is absent the quarrying of these stones is more difficult because there is no rift as in the granites and the ordinary jointing is irregular. The darker rocks of the group are sometimes called "greenstones" or "trap-rocks."

3. *Porphyritic rocks* do not properly form a class by themselves, for nearly all the types of rocks may exhibit porphyritic structure (p. 16). Yet this structure, when well developed is so obvious and the porphyritic rocks are so frequently objects of interest and beauty that they deserve a separate position among the decorative stones. The minerals most commonly observed as porphyritic crystals, standing out from the other constituents of the stone on account of their larger size, are the felspars, amphiboles and pyroxenes; though, quartz, mica and many other minerals occur with this habit.

4. *Vesicular igneous rocks* are most common in the volcanic lavas that have been filled with cavities caused by the expansion of the steam within them when the

molten rock was extruded. The structure is common in rhyolites and trachytes, and it is found in andesites and basalts. In some districts such stones, though porous, are used for building, but the most useful varieties are the extremely vesicular pumice stone and the hard vesicular andesitic, trachytic, and basaltic rocks used as millstones (p. 84.)

5. *Fragmental volcanic rocks* occur in the form of loose and often extremely fine volcanic *dust*, frequently called " ash " from its ash-like appearance. When the dust deposits have solidified on the ground or under water they are described as volcanic *Tuffs*; when larger fragments are present the rock is a volcanic breccia or agglomerate, and if they are rounded it is a volcanic conglomerate. Acid tuffs are more common than basic ones; tuffs are classed according to their mineral and chemical composition, that is, in accordance with the parent rock type, for instance, we speak of rhyolite-tuffs, trachyte- andesite- or basalt-tuffs. Some tuffs make light and porous but satisfactory building material in dry climates; others, such as the *Trass* of the Rhine valley or the *Puzzuolana* of Italy are utilized in the manufacture of cement.

CHAPTER X

EMPLOYMENT OF STONE—BUILDING AND ENGINEERING

Employment of Stone in Construction. Stone is employed in various forms of construction; these may be conveniently considered under the following subheads: Building, Engineering, Roads and Paving, Decoration, Monuments.

Building. The art of building with stone is a very ancient one, though no doubt the use of this material was preceded by the employment of less difficult materials, such as wood, earth or turf, and it is most likely that the earliest stone buildings were constructed of the rough loose blocks that in many regions are found ready to hand upon the surface of the ground. But in the earliest civilizations, where stone was available, considerable skill in its manipulation was achieved, indeed, in some instances the only evidence that survives of the former inhabitants lies in the buildings erected by them.

The kind of stone employed was naturally determined by what was readily available; in the humble dwellings of the poor in all ages, in the massive walls of ancient cities, and in the castles of mediaeval lords, stone of all sorts is found, good and bad. When, however, the state of civilization of a community became sufficiently complex or when some of its members became sufficiently wealthy and leisured, efforts appear to have been made to secure and employ the best available material, even if it necessitated transport for considerable distances and an enormous output of labour.

At the present time, in different parts of the world, the most diverse stones are employed for common buildings because the choice is limited by the geological characters of the district. Thus the prevalent stone may be granite, basalt, sandstone, limestone, slate, or it may be schist, gneiss, fresh coral rock, chert, flint, or mixed boulders of glacial origin. Many of the stones used locally would be quite unrecognized or regarded as unsuitable in other parts of the world. In consequence of this diversity in stone used in common building we find the local geological conditions faithfully reflected in the character of the houses of different districts, accompanied not infrequently by peculiar methods of construction that have been adopted to suit the material. Thus the practice of employing flint as a facing stone is limited to those counties where the flint-bearing Chalk or derived flint gravels are found; while the use of Chert as a building stone is restricted to the south-western counties, where this stone is well developed in the Greensand.

In considering stone for good class building we are not dependent upon purely local conditions, the chief factors that determine the use of stone are its appearance, durability, cost and suitability for the design.

The appearance is dependent on the colour and texture; the stone may give the effect of warmth or coldness, of softness or hardness and strength. Further, the appearance will be influenced by the nature of the surroundings, in country situations stone buildings will retain almost indefinitely the appearance they had when new, though they will be softened and mellowed as time goes on; a sandstone that in Manchester will rapidly assume a uniform and dingy blackness keeps its freshness almost untarnished in a house like Chatsworth, in the midst of park and woodland, or, after some

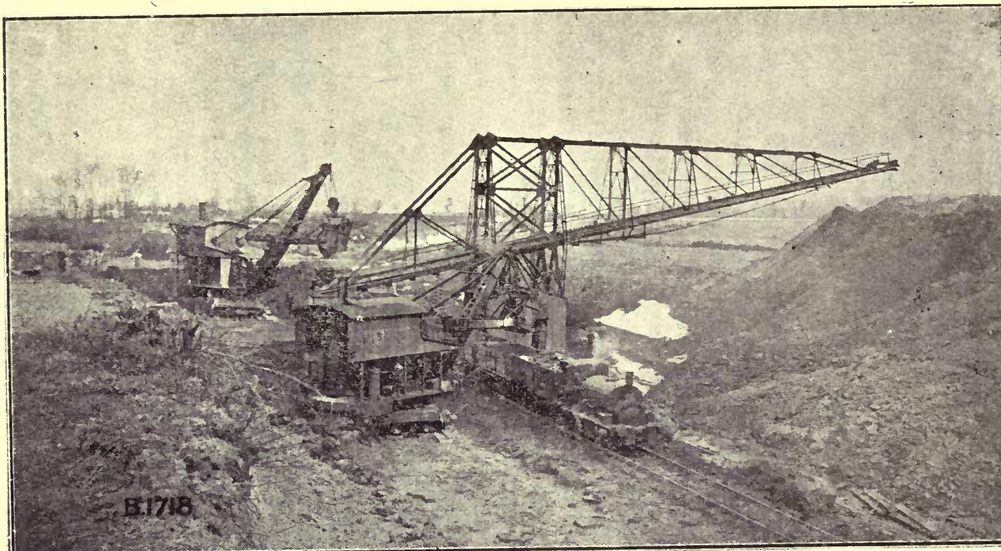


Fig. 16

RUSTON AND HORNSBY STEAM NAVVIES DIGGING AND LOADING IRONSTONE: TRANSPORTER REMOVING OVERBURDEN TO DUMP

centuries, as in Haddon Hall, near by, it takes on harmonious and pleasant shades of grey. The future aspect of stone-work should always be considered in making the choice of stone. It is useless to trouble to secure a red or yellow sandstone for a building which will turn black before many years have passed.

As regards durability, if the stone selected for its appearance is one that is well known and has been freely used, we can judge its comparative durability from the accumulated knowledge of its behaviour and from observation of existing buildings. If the stone has not been used before, then it should be subjected to careful preliminary examination, and for some purposes it may be necessary to apply certain tests (p. 69), though the surest test of all is the behaviour of the stone as observed in its natural outcrops, when this is possible. Durability will much depend upon the way the stone is treated; soft stones should not be placed where they will get rubbed; stones with marked lamination or bedding should be laid flat on their bed; elaborate carving means early blurring. Flush ashlar will always last better than more irregular or richly moulded work. Durability depends most upon the weathering properties of the stone, and is comparatively rarely affected by its strength, except in cases where lintels, etc., are made too long for their resistance to bending or shearing stresses. It should always be borne in mind that it is the odd bad stones that first show deterioration; even with stone of proved excellence, selection at the quarry and by the mason is of vital importance for the highest class stone-work.

The question of cost is not infrequently the factor that determines the final choice even when it entails the loss of some degree of suitability or durability. In general, the granites, harder sandstones and limestones

cost more for getting and dressing than the softer stones. The transport charges have also to be considered. Care has to be exercised to secure that a sufficient supply of the stone is obtainable in blocks of the dimensions required, for it may greatly add to the cost to discover after selecting a stone and placing the contract, that the quarry is really incapable of producing the needed quantity.

Decay of Building Stone. All kinds of stone, when exposed, suffer disruption and decay from the attack of rain, wind, frost and heat, and from the activities of vegetable life. The cumulative results of the action of these agencies is known as "weathering"; a good "weatherstone" from the builders' standpoint is one that offers satisfactory resistance to these destructive forces. Naturally, much depends upon the climate, stones that will remain unscathed for centuries in a dry climate will show signs of wear after a few years exposure in a climate like that of Great Britain.

Weathering operates both chemically and mechanically. The solvent power of rain-water, mainly due to its content of carbonic acid, produces only moderate effects in inland country buildings but much more striking results in towns, where the products of combustion yield an acid-laden atmosphere; also at the sea side, where saline spray increases its solvent power. Stones are sometimes attacked by saline solutions creeping up from the ground or leaking out of the cement in which they are set. Lichens and mosses damage the surface of stones by the chemical action of their secretions and by the vital force of growth, also by affording lodgment for water and dust.

On the whole, the mechanical disintegration of building stone is a more general cause of decay than solution; though the former facilitates the operation of

the latter. Disintegration of stone is induced by the action of *frost* which tends to remove flakes from the surface of stones if they are frozen while charged with water; hence the desirability of keeping stone as dry as possible by avoiding forms which provide resting places for moisture. It is also brought about by simple *changes of temperature* which cause repeated expansions and contractions of unequal magnitude in the different mineral constituents and open out the cleavage planes in minerals with good cleavages like calcite and the felspars. *Wind*, bearing sand and dust will frequently cut deeply into exposed buildings.

The effect of these weathering agencies differs on different stones. In *limestones* chemical weathering is most noticeable, particularly in town buildings, for in addition to the increased content of carbonic acid in the rain-water, there is added a certain amount of sulphurous acid, which eventually converts the carbonate of lime to gypsum, and when this is not removed readily by the free flow of rain, as in some forms of mouldings and cornices, it may accumulate as a thick crust, blackened with soot. Limestones with open or clayey seams exhibit a kind of suppuration along the seams from the same cause. On the other hand a homogeneous limestone, like Portland stone, will usually wear away very evenly. Coarsely crystalline white marbles become mealy on the surface owing to the mechanical opening of cleavages in the crystalline grains by frost changes and of temperature. *Sandstones* give way in the bonding material and along lamination planes when these are present. *Granites* suffer little from solution, their decay is very slow and is due mainly to mechanical agents. *Slates*, if they are absorbent, suffer from frost, otherwise they are very resistent.

Testing of Building Stones. The best test of building stones is experience; but in order to obtain criteria for measuring the strength and durability of untried stones many attempts have been made to estimate these qualities by subjecting the stone to physical and chemical tests of various kinds; it must be admitted, however, that the vast number of experiments that have been made have proved of little value in actual practice.

Stones are tested for resistance to (1) compression (crushing strength), (2) shearing, (3) bending, (4) tension, (5) abrasion and attrition, (6) corrosion and (7) freezing, also for their (8) elasticity and (9) porosity and absorption of water. Tests have also been applied to determine the comparative resistance to weathering by the exposure of samples under controlled conditions. Chemical analysis and microscopic examination are also applied.[1]

The following simplified results may be taken as a guide for calculating the strength of masonry.[2]

ULTIMATE STRESSES IN TONS PER SQUARE FOOT.

	Crushing.	Tension.	Shearing.	Bending.
Granite . .	900	30	50	100
Basalt . .	800	80	40	—
Slate . .	800	10	30	50
Sandstone .	500	10	30	50
,, (soft)	200	5	10	20
Marble . .	600	30	50	—
Limestone .	500	25	40	60
,, (soft)	100	9	35	50
Chalk . .	10	—	—	—

[1] See Howe. *The Geology of Building Stones*, for a discussion of the results of these and other methods of testing stone.

[2] H. Chatley, *Stresses in Masonry.*

2. Stone in Engineering. For engineering construction stone is required in several forms. For dressed work in bridges, piers, embankments, breakwaters, dams and docks the requirements are like those for ordinary building, the main difference being that the choice is limited to the harder and more durable stones which must often be of large dimensions; consideration of appearance does not take the prominent place it does in ordinary building.

For large works like docks, embankments and large bridges granites are most favoured, partly on account of the durability of good stone of this class and partly because stones of suitable dimensions are readily obtainable in considerable quantities. Massive sandstones and limestones may be used in place of granite but limestones are unsafe for marine work, mainly on account of the destructive action of boring organisms. Much will depend on the kind of wear the structure will be called upon to bear; thus if it is exposed to the beating action of waves and shingle the hardest and toughest stone is required, all joints must be as close as they can be made and massive blocks must be employed.

Very large quantities of rough stone are required for rough retaining walls, backing dams and the like, this should be strong and not prone to crumble or shatter too easily.

Very large quantities of screened gravel or broken stone are also used for making concrete. For this purpose likewise there is a wide range of choice. The principal considerations are that the stone should be sufficiently hard, that it should be free from clay and soil, and that it should be properly graded. Broken stone is also used on a large scale for railway ballast.

CHAPTER XI

EMPLOYMENT OF STONE—ROADS AND PAVING

Broken Stone for Roads. Immense quantities of stone are required for roads. In thinly populated regions any sort of stone is employed without much selection, from strictly local materials, because lengthy transport cannot be undertaken. Thus, in parts of the United States roads made of well-mixed sand and clay have proved quite efficient under light traffic. In parts of India and Africa very fair roads are made of the ferruginous surface deposit known as laterite.

The result of the heavy demand for high grade stone is, that instead of keeping open a large number of small quarries working and hand-breaking stone of very variable quality, it has stimulated the development of large quarries in good stone, provided with facilities for machine-breaking and screening.

Broken stone is used for roads made with the natural bond provided by the stone itself, and since these are laid wet they are sometimes spoken of as "water-bound," also for roads bonded with bituminous substances and tar or with cement in the foundations of wood roads.

Since the majority of roads are still essentially of the water-bound type we may consider the qualities demanded of stone for this class of road. As regards shape, the stone should not be too flaky, a roughly cubical form is best, this depends mainly on the character of the stone but partly on the manner in which it is broken. The stone should have a high resistance to attrition, it should be hard and tough, its powder should possess considerable cementing power, but there should

SELECTED EXAMPLES OF AMERICAN TESTS ON ROAD-STONES.[1]

Number of Samples	Stone.	Specific Gravity.	lbs. per Cub. ft.	Absorption.		Percentage of Wear.		French Co-efficient of Wear.		Hardness.		Toughness.		Cementation.	
		Average.	Average.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
83	Basalt . .	2·85	178	6·32	0·04	14·7	1·3	30·7	2·7	19·2	5·9	39	6	500+	4
183	Diabase .	2·90	181	2·73	0·03	6·3	1·1	36·4	6·4	19·4	12·3	54	4	500+	2
40	Andesite .	2·70	168	6·59	0·05	8·1	1·5	26·0	4·9	19·4	7·9	44	6	500+	11
11	Felsite .	2·65	165	3·13	0·02	3·4	1·9	21·3	11·8	—	—	—	—	—	—
35	Rhyolite .	2·55	159	7·15	0·03	9·7	1·7	23·0	4·1	19·7	15·3	42	6	500+	10
168	Granite .	2·65	165	2·77	0·04	24·6	1·1	37·0	1·6	19·6	13·6	33	2	255	2
26	Syenite .	2·70	168	4·21	0·08	14·4	1·7	23·5	2·8	19·2	17·3	34	8	375	16
115	Gneiss . .	2·75	172	1·24	0·02	16·4	1·7	23·0	2·4	19·3	9·0	25	2	110	1
36	Gabbro .	2·95	184	0·97	0·04	5·9	1·3	30·8	6·8	18·8	16·2	23	9	115	6
573	Limestone.	2·70	168	13·22	0·02	34·2	1·8	21·7	1·2	19·1	0·0	25	2	500+	10
20	Marble. .	2·75	172	1·04	0·10	14·0	2·5	16·0	2·8	17·3	7·1	23	3	85	15
244	Sandstone	2·65	165	11·60	0·02	41·7	1·0	40·8	1·0	19·5	0·0	60	2	500+	1
78	Quartzite .	2·70	168	1·89	0·05	7·6	1·6	24·5	5·3	19·7	16·5	30	5	45	0
114	Schist . .	2·90	181	1·35	0·06	18·2	1·3	31·7	2·2	19·0	0·9	35	3	232	5
45	Slate . .	2·75	172	2·10	0·05	12·4	1·6	24·4	3·2	19·7	1·1	56	1	500+	1

[1] U.S. Bureau of Public Roads, Bull. 31.

not be so much of it as to make the road muddy in wet and dusty in dry weather; it should not be too absorptive and its special gravity should be fairly high.

It must be recognized that no single stone possesses all these properties in their highest degree, and that different lengths of the same road demand rather different qualities in the stone. Thus, one stretch of road is shaded by trees and subjected to frequent drip from them; another is on a wind-swept brow; parts are steep, others are flat, so that it is often desirable to treat sections of the same road differently.

In order to find out the comparative wearing capacity and other qualities of stone for road-making a series of tests have been devised. Some of these were first carried out in France but the most accessible data at present are those prepared by the United States Bureau of Public Roads. The Table on page 72 is an abbreviated list of some of the tests carried out by the Bureau.

This list by no means covers all the kinds of stone that have been used and tested for roads, but it shows the properties of a sufficiently wide range of stones. Much more could be learned from it if space permitted of the introduction of the full data for each batch of stone tested, but several important facts appear from the examination of these results.

It is clear that many stones were tested which no self-respecting engineer would have thought of using; it is also evident that good roads could be made from the *best* stones of each of the classes; consequently there is no safety in specifying the use of any particular kind of stone without a safeguarding clause demanding that the stone shall pass definite tests or that it shall be supplied from sources of repute.

Some of the outstanding qualities of the main types of road stone may now be briefly mentioned.

Granites. Fine grained granites make very fair road metal; coarse-grained granites should not be used except in the foundations. The cementing value is low and they are never so good as the classes of stone with a more felted or intricate texture.

Syenites are usually superior to granites, especially when fine-grained and with some secondary mineral alteration.

Greenstones. This old-fashioned field name serves very well in this connection to cover the dark coloured, often greenish igneous rocks such as basalt, dolerite, diabase and some andesites, porphyrites, diorites and finer gabbros. The best of such rocks make the finest road stones.

Felsites and *Rhyolite* and similar fine-grained acid rocks come very near the greenstones, though as a class they are rarely so tough.

Limestones are very variable; the better ones make good roads for light traffic or used as a top layer over a harder stone, but they tend to be dusty or muddy and greasy according to the state of the weather.

Sandstones usually crush down too readily to sand, but some tough felspathic and argillaceous sandstones make fair roads.

Quartzites are tough and wear well, the chief objection to them is the low cementation when used alone.

Schists and Slates rarely make really good roads on account of the shape of the pieces.

Gravel obtained from old river deposits or sea beaches is often of mixed composition both as regards the stone and the interstitial matter; the latter is clayey or sandy. Material of this class is often useful road stone, but it is customary to require it to be screened to different sizes, and it may also have to be washed. The flint gravels of the Thames valley have been extensively

used for roads; the stones are subangular, but more or less rounded quartzite is often present.

In general, it is found that stone in which secondary mineralization has taken place is tougher than the fresh rock of the same kind because the larger original mineral elements have been more or less replaced by a finer and better knit together aggregation of new minerals, among which secondary silica is usually prominent.

Some stones break better to one size than another, but the dimensions commonly specified are as follows—Macadam 3 in., $2\frac{1}{2}$ in., 2 in. and $1\frac{1}{2}$ in. Chippings are supplied in the following sizes: 1 in. $\frac{3}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{8}$ in., $\frac{1}{4}$ in. and $\frac{1}{8}$ in.

Note. A large collection of British roadstones with microscopic sections and the results of tests made by the National Physical Laboratory, may be consulted at the Museum of Practical Geology.

Road Paving. Stone for this purpose is supplied in the form of rectangular blocks called "setts." The qualities required in sett stone are (1) a fairly easy straight-faced fracture, otherwise the cost of production becomes too high, (2) correct dimensions, (3) toughness, and (4) wear to a fairly rough surface.

Setts are laid upon a layer of sand resting upon a substantial foundation and finished to the required camber. The setts are grouted with pitch or bitumen or cement.

Granite of medium grain is one of the most commonly used sett stones on account of its good qualities in wear and the comparative ease with which it can be dressed. Basalts, and other greenstones are used; they should be the coarser varieties, otherwise they may wear too smooth. Quartzite when tough makes good hard-wearing setts.

Stone Pavements may be constructed of (1) flagstones, (2) setts, (3) cobbles, (4) mosaic.

The form of stone principally used for pavements and side paths is the flagstone or flag. The kind of stone employed will depend on circumstances. For the ordinary street side-walk a sandstone is by far the best and the most used. Any hard, well-bedded sandstone may be used which can be split along the bedding or sawn so as to make slabs 2 in. thick or over. The best known natural paving slabs come from the Coal Measure sandstones of Yorkshire and Lancashire, some of the better known rocks in Yorkshire are the *Elland Flagstone,* quarried about Halifax, Elland Edge, North and South Owram; the *Penistone Flags; Oakenshaw Rock; Park Gate* or *Birstal Rock;* the *Thornhill Rock,* quarried at Oulton and Morley. In Lancashire are the *Upholland, Rochdale* and *Burnley Flags* and the *Woodhead Hill Rock.* The Old Red Sandstone of the north-east of Scotland, particularly Caithness, yields dark strong flags of great repute.

Most natural sandstone slabs scale a little after long exposure, as one lamina after another is worn through, but they retain a good rough surface.

Other stones used for pavements are limestones, such as the well-bedded blue (some are white) Lower Lias limestones, quarried in the counties of Somerset, Warwickshire and Worcestershire. These stones wear well but are rather slippery for outdoor use. The white paving in the Law Courts and Houses of Parliament is from the quarries at Wilmscote. The Carboniferous limestones are used more locally for paving. For indoor work the *Hopton Wood stone* is suitable. The Permian, *Mansfield stone,* a red or white sandy and dolomitic limestone, wears well; the two colours are employed on the terrace in front of the National Gallery.

Among the Jurassic rocks the harder varieties of *Portland stone* form a favourite material for internal flooring, and wear well and do not get very smooth. Locally, other limestones are employed from the same geological system, for instance, the Forest Marble, and the Great Oolite, at Bedford. In slate-producing districts this stone is freely used and flaggy schists are often employed in the same way.

Setts are not often used in pavements, but cobbles are much used in country districts and especially in continental towns. Cobble pavements are made of roughly squared stones, or more commonly of large pebbles set well into clay or mortar. These pavements are not very pleasant to walk upon but they are exceedingly durable.

Mosaic pavements are used mainly for interior work. Any of the harder stones may be employed, arranged according to their colours to form patterns. The stones have to be correctly squared or shaped, and they are laid on a prepared floor in various kinds of cement, the whole floor being afterwards smoothed by means of a holystone. In larger-patterned mosaic the individual slabs may be previously polished. For some kinds of mosaic flooring artificially made cubes are used; in another type of floor a cement paste is filled with small fragments of marble and the whole rubbed smooth; this is called Terrazzo flooring.

CHAPTER XII

EMPLOYMENT OF STONE—DECORATION AND SCULPTURE

Stone for Decoration. The stones used for decorative, purposes embrace the more brightly coloured granites diorites, syenites, dyke rocks or elvans, and more rarely gabbros from among the igneous rocks; marbles, including serpentine, onyx-marbles, and alabaster; and less frequently, because they are less common, other kinds of stone when they possess attractive qualities of colour and marking.

Stone is employed for decoration in different ways: it may be used (1) in decorative construction, (2) as an applied decorative material, (3) in carved or sculptured ornament, (4) for making minor ornamental objects.

1. In *Decorative Construction* stone is employed for such purposes as frontages, for lower storeys of business and other buildings in towns, for staircases, supporting columns, floors, and in churches for screens, pulpits, fonts, reredoses and the like. In this class of work the decorative stone approaches a building stone in its mode of employment and partakes of a constructive as well as a decorative function. For frontages the stones most in use are the granites and rocks of that class, or the more massive marbles; they are employed with a polished or rough face.

Serpentinous marbles are occasionally used for frontage decoration but usually with poor results, for they tend to become dull and grey on the surface and the numerous flaws are apt to develop and enlarge.

For staircases and balustrades in interiors marble of all kinds can be used with good effect. Highly coloured marbles, when used as flooring slabs, tend to wear dull and grey if there is much foot traffic; marbles with a rather coarse granular texture are particularly subject to this defect.

2. *Applied Decoration.* For this purpose the stone is sawn into thin slabs and fixed to walls and ceilings, sometimes with the object of providing large flat surfaces of uniform tint but more often there is a scheme for the employment of different tints in dados, string courses, panels, etc., with or without mouldings. Any of the decorative stones may be used in this way for internal work but the marbles, onyx marbles, serpentine and alabaster are the most common. Veneers of stone should not be used in external work.

Mosaic. The art of inlaying stones was developed to a high degree by the Romans who appear to have borrowed it from the Greeks, who in turn probably took it from the Persians. The earliest form of mosaic was the *opus tesselatum,* in which small cubes or *tesserae* were arranged in simple patterns on a carefully prepared surface; later glass and ceramic tesserae were introduced along with the cubes of marble, this was the *opus figlinum,* which had a considerable revival in the sixteenth century, and was known as "Roman mosaic." The use of thin slabs of marble, let into larger slabs of black or white marble, etc., appears to have originated about 100 B.C.; this was the *opus sectile.* The method was revived in the Renaissance in Italy for geometrical patterns and the representation of natural objects and scenes; it is now called "Florentine Mosaic." The practice of making designs on white marble slabs by cutting thin channels in them and inserting dark-coloured marbles, the *opus alexandrinum,* was in use

from the third to the thirteenth century; later it was developed in India. The use of irregular tesserae for *terrazzo* floors has been mentioned on page 77.

Pietra dura is a variety of inlay work in relief employed in Italy for small ornaments representing fruit, flowers and the like in coloured stones.

Stones for Monuments and Sculpture. The stone required for monuments and memorials must necessarily differ according to their purpose, situation and design.

For monumental purposes the use of stone may be considered under (1) outdoor, and (2) indoor conditions.

1. External monuments, with which we may include tombs and tombstones, memorial crosses, fountains, sculptured figure groups and plinths for figures of bronze, garden ornaments and high relief work applied to buildings, all require stone possessing the following qualities. The stone must be *durable;* the remarks upon the weather-resisting properties of building stone (p. 67) are applicable, but with much greater force to stone used for these purposes, for it will be much more exposed and will thus offer itself more completely to the attack of the weather and the greater the elaboration of the design the more rapid will be its obliteration.

Next, the stone must be suitable in *appearance* to the purpose for which it is used, to the design and to the surroundings in which the structure is placed. This naturally involves questions of some difficulty in which personal feeling must be allowed for, but the different qualities of stone in colour and texture must obviously be taken into consideration. Stone may produce an effect of warmth, mellowness, or cold, according to its colour and tone; it may suggest hardness and strength or softness according to its texture and the way it is treated.

The natural markings of stone should not be such as

would interfere with the lines or the shadows of the design; accidental blemishes in a stone should cause it to be discarded for the same reason.

Granite is used for all classes of monumental work and in durability it is superior to most of the stones employed. A matt surface is most commonly applied. Granite takes carved enrichment well and low relief designs are frequently employed. Occasionally parts of the design or lettering are polished, and the background kept dull, but the result is not invariably satisfactory. Diorite, syenite, and some of the finer-grained and porphyritic dyke rocks are employed in the same way and behave similarly.

Basalts and the more basic rocks are seldom used unless there is some special reason for a dark and sombre effect. They are not usually obtainable in large dimensions of suitable quality.

Sandstones might be employed more often than they are for bold designs. Only the more homogeneous limestones are suitable for external carved work. Slate is an excellent stone for tombstones, it takes lettering well and is very durable.

For internal memorial tablets and sculpture it is possible to use many of the softer stones.

CHAPTER XIII

EMPLOYMENT OF STONE—MISCELLANEOUS USES OF STONE

Stone for the Manufacture of Lime and Cement. One of the most important commodities manufactured from stone is lime, made from limestone by burning at a red heat; the change thus produced in the stone may be represented by the equation—

Limestone, heated = Quick lime + Carbon dioxide gas.

$$CaCO_3 = CaO + CO_2$$

There are three principal types of stone which on being burnt yield three corresponding types of lime; they are—

1. Pure limestones, yielding *high calcium limes.*
2. Magnesian limestones yielding *magnesian limes.*
3. Argillaceous and siliceous limestones yielding *hydraulic limes.*

The burning of limestones is effected in kilns of which there are many different forms in use; most of them fall within the following types—

1. The field or D. kiln for small output.
2. Vertical kiln with mixed or separate feed.
3. Ring or Hoffmann kiln.
4. Rotary kiln.

Lime is marketed as " Run of the kiln," " Selected lump," " Ground lime," and " Hydrated lime." Limes are said to be " fat " or " rich " if they more than double their volume during slaking and at the same time evolve much heat; they are " meagre " or " poor " if they do not increase to twice their original volume and slake rather more slowly.

Cement. Enormous quantities of limestone, chalk, clay and shale are absorbed by the Portland cement industry. There are also natural stones that can be burned to a cement clinker without admixture and volcanic tuffs that make a special type of cement, such are Puzzuolana and Trass. The cement industry is fully described in a separate volume of this series.

THE USES OF LIMESTONE CONVERTED TO LIME. The fact that lime is a cheaply made alkaline substance and that it hardens or sets on exposure to air, has caused it to become of great importance in many branches of industry.

The purposes to which it is applied may be grouped under the following heads—

1. Construction.
2. Agriculture.
3. Manufacture.

(1) In construction, building and engineering, lime is required for mortar, finishing lime and plaster, sand-lime bricks, and indirectly in the manufacture of Portland cement and Roman and other natural cements.

(2) In agriculture lime acts as a plant food directly and indirectly, and improves the texture of many soils; besides acting as an insecticide and fungicide.

(3) Lime is employed in the following industries—

Bleaching of rags, jute, ramie, and various paper stocks (c.m.)[1], and in the manufacture of bleaching powder, so-called " chloride of lime " (c.).

For the purification of coal gas and water gas (c.m.).

In glass manufacture and for various glazes (c.).

For " clarifying " grain in the milling industry (c.m.).

[1] " c " indicates that a calcareous lime, " m " that a magnesian lime is employed.

For the manufacture of soda, potash and ammonia; calcium carbide, cyanamide, and nitrate; potassium dichromate and sodium dichromate; acetate of lime, wood alcohol, bone ash, various fertilizers; soap, glycerine, candles, lubricating greases.

Lime is employed in refining mercury (c.), dehydrating alcohol (c.), dyeing fabrics (c.m.), in making rubber (c.m.), glue (c.m.), pottery and porcelain (c.m.), in removing fats (c.m.), and removing the acidity of oils (c.m.).

In the paper industry lime is used in the soda method (c.) and the sulphite method (m.); also for strawboard (c.m.), and as a paper-filler (c.m.).

Lime is used for distempers and cold-water paints (c.m.), for the manufacture of linoleum (c.m.) and varnish (c.m.).

In the sugar industry (c.), in tanning (c.m.), in smelting (c.m.).

In sanitation as a disinfectant and deodorizer (c.), for the purification of sewage (c.), and for softening and purifying water (c.).

It is also used for the preservation of eggs (c.), as a polishing agent (c.m.), and many other minor purposes.[1]

Stones for Abrasion, Grinding and Polishing. Considerable quantities of stone are used for these purposes. *Millstones* are made of coarse gritstone; French Buhr stone, a cellular silicious stone, from Seine et Marne and Niedermendig stone, a vesicular lava from the Eifel district, are widely employed as millstones; both have a high reputation. *Grindstones* for sharpening tools, shaping metal work, preparing wood for pulp and similar purposes are commonly made of gritstone,

[1] E. F. Burchard and W. E. Emley: *The Source, Manufacture, and Use of Lime,* Mineral Resources of the United States for 1913 (1914), Pt. II, p. 1592.

obtained in this country, principally from the Coal Measures and Millstone Grit. *Sythestones* are made from moderately fine-grained porous sandstones. *Whetstones, oilstones* and *hones* are fashioned out of various kinds of slaty rocks and fine siliceous stones. Their abrading qualities are due to minute particles of quartz and occasionally of garnet and other hard minerals. The following are some of the better known varieties: Water of Ayr or Scotch snake stone, Turkey stone, Washita and Arkansas stones (novaculite), Deerlick stone, Hindostan or Orange stone, Norway ragstone. *Grinding Pebbles*, used in tube mills and the like for grinding cement clinker, ores, etc., to powder, are selected flint pebbles, but other hard pebbles are also employed.

Pumice stone is used in lumps or as powder for smoothing and polishing. *Rotten stone* and *Tripoli* consist of finely-divided siliceous particles, often the result of the decomposition of impure limestones; they are used in polishing pastes and powders. *Diatomite* or *Kieselguhr*, composed of the minute siliceous skeletons of the plants called diatoms, is found in bedded deposits and is similarly employed. *Sand* is used as an abrasive in scouring, dressing and sawing stone, etc.; it is also employed in the sand-blast for cleaning and cutting patterns, also as sand-paper and as Bath-brick.

Refractory or Heat-resisting Stone. Even in prehistoric times the value of a heat-resisting stone was appreciated, and certain stones were fashioned into "pots" to be put in the fire for cooking food; frequently these were made of a more or less pure steatite rock (p. 13), called *pot stone* on account of this usage. *Fire stones* were of different kinds, often sandstones, that acquired a local fame from their ability to withstand the heat of fireplaces and furnaces without cracking or spalling. A well-known firestone in the South of

England is that from the Upper Greensand of Reigate and Merstham; others were obtained from the Carboniferous sandstones of Yorkshire, Staffordshire and elsewhere. Mica-schist has been employed as a furnace lining with tolerable success. A fine-grained quartzitic sandstone called *Ganister*, obtained from the Lower Coal Measures of South Yorkshire, Derbyshire, Durham and Lancashire, and other fine-grained quartzitic sandstones from other parts of the Carboniferous formation, called *Silica-rock*, are employed on a large scale as refractory material; the Dinas rock of South Wales is a well-known variety. There is no very sharp line between ganister and silica-rock; both are ground to form ganister mixtures or ground-ganister for lining acid Bessemer furnaces and forming the hearth of open-hearth acid steel furnaces; they are also ground under edge-runners in pans (see Fig. 27), and after being mixed with about 2 per cent. of lime are made into silica-bricks for the construction of furnaces and coke-ovens. Besides the Carboniferous silica-rocks mentioned above, others are obtained from Pre-Cambrian of Anglesey and parts of Scotland, the Cambrian of Warwickshire and Worcestershire, the Ordovician of Shropshire and the Jurassic Estuarine series of North Yorkshire; Bunter pebbles of quartzite are also used.

The output of quartzitic stone for refractory use during 1917 in the United States was over 1,250,000 tons.[1]

Refractory sands, fairly pure quartz sands, are required for the hearths of acid steel furnaces, reheating furnaces, etc. Fontainebleau sand from France, Belgian sand and others from the Lower Greensand

[1] *Special Reports on the Mineral Resources of Great Britain*, Vol. VI, Refractory Materials, London, 1918.

formation of Leighton Buzzard in Bedfordshire, Aylesbury in Bucks, and King's Lynn in Norfolk, are so employed. Occasionally friable, pure sandstones are crushed for the purpose. Very pure silica-sand is used in making fused silica for laboratory and chemical works apparatus.

Sandstones and some silicified igneous rocks that are refractory to the action of acids are needed in certain chemical works.

For basic furnaces, where the basic slag formed would rapidly eat away the silica-bricks or ganister hearth, a basic refractory material has to be used; for this purpose bricks made of magnesite and chrome ore are employed, and for the hearths, broken calcined dolomite is laid in place of ganister. The dolomite is obtained from quarries in the Permian Magnesian Limestone of Steetley and elsewhere on the borders of Yorkshire, Nottinghamshire and Derbyshire, and in Durham at Coxhoe and Raisby. It is also obtained from dolomitized beds in the Carboniferous limestone of Porthywaen, Salop, Threshfield in Yorkshire, Harboro' Rocks, Derbyshire, and in Brecknockshire, Glamorgan and Monmouthshire. The stone is calcined in tall vertical kilns or cupolas.

China-stone, a variety of granite, free from dark minerals, found in Cornwall, is employed when ground in the manufacture of pottery and porcelain. **Flint,** calcined and ground, is similarly employed.

Gypsum, hydrated calcium sulphate, consists when pure, of lime 32·6 per cent., sulphur trioxide 46·5, and water 20·9 per cent. It is found interbedded with clay, sandstone or limestone, and is often associated with anhydrite and rocksalt, in the Permian, Triassic and Jurassic rocks in England, also in Tertiary strata in France; it is a widely spread rock found in many parts

of the world. The output in Great Britain in 1913 was 285,000 tons. It is quarried and mined in Nottinghamshire, Staffordshire, Sussex, Derbyshire, Somerset and Westmoreland.

Plaster of Paris is made by grinding the gypsum and heating it in vessels while being stirred, until about half or one-third of its water is driven off; this process is called "boiling." The boiled plaster when wetted sets in about fifteen minutes; the setting is due to its recombination with the water to form a felt-work of gypsum crystals. Plaster is marketed in several grades differing in fineness and colour; it is also sold under numerous proprietary names. Large quantities of plaster are used for walls and ceilings and for making moulds in pottery, sanitary ware and terra-cotta manufacture, also for making casts of all kinds of objects.

Gypsum cements are made by treating plaster with alum, carbonate of soda or potash, borax and other substances.

Terra-alba or *mineral white* is finely-ground gypsum, graded according to its purity and freedom from included "marl"; it is very extensively employed in the manufacture of paints, as a paper filler and in "finishing" cotton and lace goods. Gypsum is also used as a fertilizer and as a manure drier, as a polishing medium for tin-plate and as a retarding agent in Portland cement.

Lithographic Stone is used in the method of printing known as lithography. For this purpose the stone must be a limestone of exceedingly fine, even texture, dense and non-absorbent. The best stones are tolerably pure limestones, but some are in use that contain a moderate amount of magnesium carbonate. The best known lithographic stones are those quarried at Solenhofen, Mörnsheim and the Jurassic limestone of that district

in Bavaria. In 1913 about 55,000 tons were exported. The stone is squared with saws and planes into slabs of 6 by 8 in. up to 40 by 60 in., the larger slabs being 3 to 5 in. thick. The upper surface of the stone is rubbed smooth with pumice.

Slabs showing veins of spar, fossils or other irregularities cannot be employed for printing; such blocks are used for leather dressing tables, mantelpieces, etc., and the thinner beds are sold for roofing or paving. In using the stones the design is drawn directly on the slab or is transferred from transfer paper or photo-lithographic paper. For line work and flat colours smooth-faced stone is used; for toned colours, where one has to be blended into another, grained stone is employed. A separate stone is required for each colour. Grease inks are used, and before taking a pull or print from the stone a wet roller is passed over it before the ink roller so that only the design, which remains dry, is inked.

The usual colour of lithographic stone is some shade of yellow buff, grey or blue. The Bavarian blue stone is the most expensive, as it is the hardest and finest in grain. The Lias limestone has been quarried for lithography in England, and similar stone has been worked in Kentucky and Iowa. Stalagmite, the so-called "onyx marble," has been tried from Utah and elsewhere. In France and Spain there are lithographic stones of Jurassic and Cretaceous age but none quite so good as the Solenhofen stone.

The place of lithographic stone has been taken to some extent by zinc and aluminium plates, but there is still a demand for good stones.

Chemical Manufacture and Fluxing. Great quantities of limestone are employed in various departments of the chemical industry as has been indicated above.

Much limestone and magnesian limestone is used as a flux in the smelting of iron and other metallurgical operations.

Miscellaneous Uses of Stone. There are many other minor uses for stone; *Hearth-stone* for whitening floors, steps, etc., is quarried from soft rocks such as Upper Greensand at Reigate, or the Chalk in South Devon and elsewhere. It is put on the market in the form of small rough cubes.

Rockery stone, for rock gardens and the like, employs a small amount of rough stone; limestones are used for lime-loving plants, and sandstones for those accustomed to a sandy habitat. Curiously-shaped, weathered blocks of stone are often selected for rockeries; calcareous tufa or travertine and gypsum are favourite materials.

Stone was often employed for making large pestles and mortars, and for boys' marbles. It was once freely used for cannon balls, and water-pipes have been found cut out of stone. Flint was formerly in demand for gun-flints and the making of strike-a-lights of flint is still an active industry in the Balkans.

CHAPTER XIV

QUARRYING

It would appear to be a simple thing to say what was meant by "a quarry," but as quarries are controlled by laws it is necessary sometimes to know what is the legal definition.

The Quarries Act, 1894, states that a quarry is "every place (not being a mine) in which persons work in getting slate, stone, coprolites or other minerals, and any part of which is more than 20 ft. deep." Again, the Quarry (Fencing) Act, 1887, describes a quarry as "every pit or opening made for the purpose of getting stone, slate, lime, chalk, clay, gravel or sand, but not any natural opening."[1] Clearly both these definitions are defective from the point of view of general usage.

The word quarry came to the English language from the old French *quarriere*, now *carrière*, which in its turn was derived from the Low Latin *quadraria*, that is, places where stone was "squared" or shaped. For the purpose of this volume a quarry will be regarded as an excavation, open to the day, made in the ground for the extraction of rock, using the word "rock" in the broad, geological sense. It may be noted here that there is a common tendency to speak of any quarry in soft or loose material as a "pit"; thus it is usual to say a "clay pit," "sand pit," "gravel pit," "marl pit," and so on.

[1] For an insight into the state of muddle and obscurity respecting the legal status of quarries and their products the reader should consult Bainbridge, *Law of Mines and Minerals,* Mc.Swinney *The Law of Mines, Quarries, and Minerals.*

Note also the Finance (1909) Act.

When an excavation for rock, stone or mineral is made underground (not open to the day), it is usually called a *mine*, and since we are dealing with stone and some stones are mined as well as quarried, it will be necessary to include some mines in this discussion.

It may be observed that some metallic ores and other minerals are quarried in the open, but these excavations are called mines on account of the nature of their output, for example the great openwork of the Rio Tinto copper mine, the Mesabi iron mines and the Mount Morgan gold mine.

In some countries the legal distinction between mines and quarries depends upon the kind of mineral substance worked; in others, the type of excavation forms the basis of the distinction.

Quarrying. From what has already been said as to the modes of occurrence of different classes of stone it will be clear that the process of quarrying must vary greatly in different circumstances.

Of prime importance is the character of the natural planes of division in the rock mass. In sedimentary rocks the *bedding planes* form one set of separation surfaces and the development of the quarry will be greatly influenced by their frequency (thin bedded or thick bedded), and by their direction (horizontal, vertical, inclined or folded). In the same rocks account will have to be taken of the direction, size, and frequency of the cracks or *joints*, for the distribution of these two sets of natural partings will determine the dimensions of the blocks obtainable and most probably also the direction of the quarry face and general method of working it.

Joints are usually more or less normal to the bedding planes, thus in horizontal beds they will run vertically; some are on a larger scale than the others and traverse

the rock for considerable distances, passing through all the beds, these are the *master-joints ;* smaller joints are less constant in direction and may pass through only a few of the beds. There is usually more than one set of joints, thus there may be two sets of master-joints, approximately at right angles, accompanied by one or more sets of subordinate joints, running in the same directions or diagonally; the joints of each set tend to be arranged in roughly parallel planes. In sandstones and well-bedded limestones the jointing is generally well developed and regular, but in massive limestones and in some igneous rocks it is often irregular. Another type of jointing produces the columnar structure of the basalts (p. 61) which may be made of great assistance in quarrying operations. With granites, in addition to the ordinary jointing there is the disposition of the sheet structure, if present, and the rift and grain to be considered. In quarrying slates everything depends upon the relative perfection of the different cleavages and their relation to the jointing. In schists and well-foliated gneisses the foliation planes form one of the principal natural partings; in some igneous rocks flow structure determines the parting direction.

Rock structures may be present that are detrimental to quarrying operations in varying degrees; such are planes of *faulting* or dislocation which may give rise to shatter-belts in the stone forming unworkable masses in the quarry, or they cause the displacement of valuable beds upwards or downwards; *veins and dykes* of unusable stone may cut through the good stone and interfere with straightforward working; *pipes* of useless material caused by the solution and removal of the stone along joints and the introduction of other rock from above may be a source of trouble.

Quarries in sand and gravel are seldom affected

seriously by these structures, and in quarries worked for stone in bulk they are of much less importance than where dimensioned stone is required.

Prospecting. In most old-established countries prospecting for stone is a comparatively simple matter because geological surveys have provided maps that indicate exactly where stones of different classes are to be found. It is true that much remains to be done in this direction, but even a small scale geological map will save the prospector an enormous amount of time and expense. In Great Britain geological maps on the scale of one inch to the mile may be obtained for practically the whole of the country, and there are considerable areas provided with geological maps on the scale of six inches to the mile, these are, of course, far superior to the smaller scale maps for practical purposes.[1]

Selection of the Quarrying Site. Among the questions to be considered at this stage the following are important—

(*a*) The extent of stone of good quality, that is, the tonnage or volume likely to be available. It may be necessary to put down a number of trial borings to prove the ground. In some cases this may be accomplished by the use of hand tackle which in soft ground will operate down to 20 or 30 ft., but for harder rocks and greater depths larger tackle is needed. The larger borings are made either by percussion or by core-drilling; in the former method the hole is made by repeated blows of the boring tool, which reduces the rock to powder as it descends, samples of the powder being extracted for examination as the work proceeds; in the latter method the crown of the drill cuts out a

[1] See *List of Maps, Memoirs, Sections, etc.*, published by the Geological Surveys of Great Britain and Ireland and the Museum of Practical Geology. H.M. Stationery Office, Annual.

cylindrical core of stone as it rotates and descends, the core being drawn up in convenient lengths from time to time, and laid out in order for reference. For quarry-proving the core-producing system is always to be recommended, though it is less rapid and more costly than the percussion method, the information obtained is much more complete.

(*b*) Overburden or cover. The stone to be quarried may run out to the surface or it may lie beneath more or less rock or earth which must first be removed.

(*c*) Accessibility to means of transport, whether by road, rail or water.

(*d*) Proximity to the markets.

(*e*) Questions touching the surrounding property; *e.g.*, way leaves, interference with public rights of way, the possibility of interferences with local supplies of water or other amenities, spaces for dumping quarry waste and so on.

(*f*) The nature of the tenure of the land, including the desirability or otherwise of securing reserve areas for future extensions.

Laying Out the Quarry. When the site has been chosen there remains the very important problem of the general plan of the quarry. It is desirable at this stage to look well ahead, to decide in what directions future expansion will proceed; if horizontally, all possible workable stone should be kept free from buildings and waste dumps; if downwards, the level of the water-table, below which water will accumulate in the excavation, must be discovered and the question of drainage must be considered and a scheme outlined for the removal of the water by gravity flow if possible, or if not, by pumping.

There is no general rule for laying out a quarry since each one has its own unique problems; it is sound practice, however, to so arrange the quarry and plant

that all movement of material proceeds in the direction of gravity, but there are many cases where this is impossible, as in the igneous rocks worked for roadstone in Leicestershire and Guernsey, where the quarries must of necessity be in the form of deep holes. It is most desirable that the disposition of crushing, grinding, or washing plant, kilns, dressing yards, store bunkers, repair shops, power-houses, explosive magazines, offices should be carefully planned at the outset so that each may be in the most convenient place during the life of the quarry.

Quarry Types. Excavations are made for stone near the surface or deep into the ground, they are made along the face of escarpments or hill sides, or by cutting right back into an escarpment, or they may be carried on entirely underground. It is possible, therefore, to group quarries according to the following types which correspond roughly with these conditions.

1. Shallow quarries, usually working over large areas.
2. Quarries with a single face, working into rising ground.
3. Quarries with a benched or terraced face.
4. Deep open quarries with a descending floor from which all material must be raised to the banks.
5. Deep open quarries with the floor at fixed level, approached by a tunnel or deep cut.
6. Underground quarries (mines).
7. Composite quarries.

Stone is mined when the thickness of the overburden or the disposition of the stone in relation to surrounding rocks or surface contours would make open working too costly. Slate, sandstone, limestone (for building), and chert are all mined as well as quarried in Great Britain; chalk has been mined in Kent.

Different methods are employed in accordance with

the nature of the stone and thickness of beds to be extracted. The simplest form of underground quarry is an adit entering the stone to be worked and leading to a series of chambers from which the stone is taken, pillars being left at intervals to support the roof. This model is well exemplified by the building stone quarry at Beer, Devon, where the beds are horizontal and a motor lorry can drive right in to the working faces for the removal of the stone.

Conditions are rather more complex in the large underground Bath stone quarries; there the beds are dipping gently and have to be approached by an inclined shaft. The ideal plan in such mines is to arrange galleries right and left of the foot of the incline along the strike of the beds and work them out towards the dip, extending the incline along the dip and making new cross-galleries as required. In practice the workings are often very irregular on plan because masses of inferior stone are left untouched. Some sandstone mines, where the beds are thick and the roof good, are worked in large chambers like an underground quarry; others, with thinner beds, are operated more like coal mines. In mining for slate the conditions are rendered difficult by the cleavage being usually highly inclined and by the large amount of waste in working. Slate mines may take the form of a series of adits run into a hill-side, one over another, to the limit of the good stone, cross-cuts being made at the end of each adit and the slate excavated thence, from chambers, back towards the entrance of the adits. In the slate mines of Angers, Northern France and Belgium there are essentially two methods in use, but with numerous modifications. In the first or Le Chatelier system, the mine is worked like a quarry of Type (4), that is, downwards in benches until they meet at the bottom of the excavation, the main difference being

that instead of an open top there is a vaulted roof pierced by a wide shaft. In the second or Blavier system, a shaft is made to the full depth of the proposed mine and the slate is then excavated from below upwards over a prescribed area (2,000 sq. m.), the refuse being used to fill the empty spaces. The shaft is best situated outside the slate area; galleries are run out to the slate with cross-cuts parallel to the cleavage. A somewhat similar method is employed at Park Slate Mine, Penrhyndsudraeth, Monmouthshire.

Getting the Stone: Extraction from the Quarry Face. The methods employed for extraction fall naturally into two main groups, in the first, quantity of stone is the chief desideratum, in the second, while output is of importance, the product must be obtained in certain sizes and shapes, or particular beds must be picked out from among others that are worthless or are required for another purpose.

In the first class of quarry stone is extracted by the quickest and most direct methods; if the rock is incoherent, like gravel or sand, or soft like clays and some shales, it may be dug by a steam navvy or by pick and shovel, according to the scale of operations. If it is a hard rock it is shaken down by blasting.

In the second class of quarry the methods employed depend principally upon the kind of stone and to some extent upon the traditions and customs of the neighbourhood. Quarrying is an art, and though the process of extraction may appear simple, a good quarryman acquires an extraordinarily intimate knowledge of the ways of stone, so much so, that he tends to become a specialist in the particular class of stone on which he has been trained. Slate, granite, limestone, marble, and sandstone, each requires peculiar knowledge to be quarried with success.

In the extraction of dimension stone it is the aim of the quarryman to get out blocks of the required size with as little waste as possible and at the lowest cost; attention, therefore, is paid to the direction and position of all existing and potential parting planes in the rock, such as joints, bedding, rift and grain in granites, cleavage and pillaring in slates, so that the fullest advantage may be taken of each.

Stone is got out by hand methods or by machinery. The tools employed in hand-quarrying bear a general resemblance in all parts of the world, but locally there are many modifications of the type forms and similar tools pass by different names.

The Wedge, sometimes called a "gad" is a useful tool for lifting blocks from the bed when otherwise free; occasionally a groove is picked in the stone and a row of wedges driven in with heavy hammers to cause a fracture along the line of the groove.

The Plug and Feathers. This is a square shaped wedge (the plug) to be inserted in a small hole between two small steel "feathers," like short rods of semi-circular section. In use, a number of small holes are drilled along the desired line of fracture at intervals depending on the character of the stone, 3 to 5 in. apart and 2½ to 5 in. deep, a plug is put into each hole along with its feathers and the plugs are then gently struck with a hammer until the stone breaks. The holes are usually round, but they may be cut to give greater mechanical advantage to the plug.

The Pick, with a fairly short and heavy head, sharply pointed is used for cutting a line for plug and feathers or for cutting a chase or channel for wedges and for other purposes.

The Jumper for drilling shot holes is a round iron rod 5 to 7 ft. long with a steel chisel cutter at one or both

ends. Some are made with a swelling about the middle (Cornwall), in other districts a cylindrical swelling is placed at one end. The hole is made by the operator standing

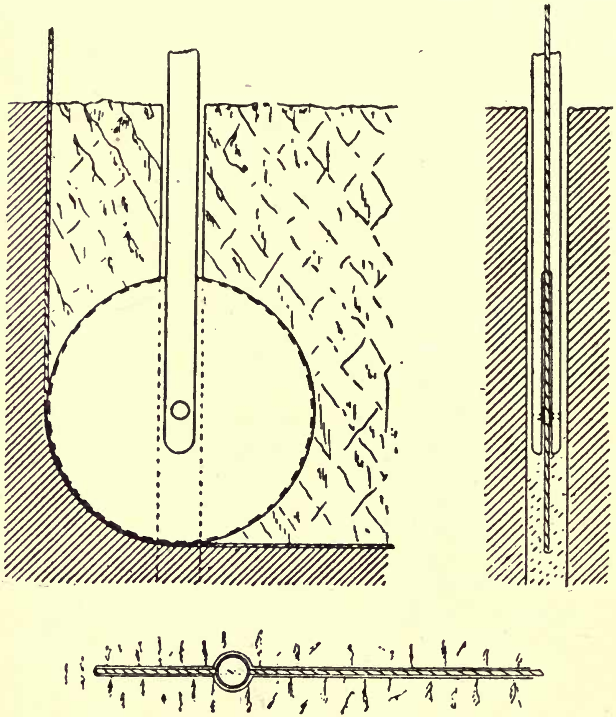


Fig. 17

THE PENETRATING PULLEY IN ACTION

and lifting and dropping the jumper and at the same time giving it a small turn in the hole; water is poured in the hole from time to time, and the sludge is removed

by a scraper. The process is known as jumping or churn-drilling.

Hand drills of various kinds and lengths and $\frac{1}{2}$ in. to $1\frac{1}{2}$ in. diameter, are used for drilling holes. A short drill may be used by one man, or a man sits with the drill between his knees lifting and turning it, while one or two others strike it with heavy hammers. A 1-in. diameter vertical hole can be cut at the rate of 16 in. per hour in granite and 30 in. per hour in a hard limestone.

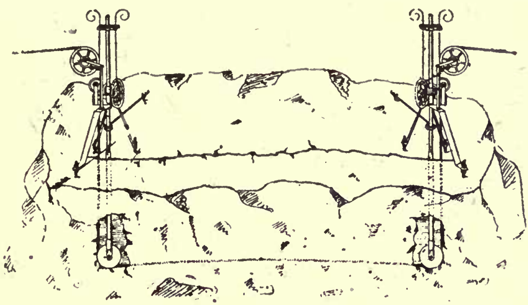


Fig. 18

WIRE SAW SHOWING PENETRATING PULLEY AT THE END OF THE CUT

Hammers and sledges are of many forms and have different local names.

Crowbars and pinch bars, some of great weight and size, are of use both in detaching stone from the quarry face and in moving blocks.

Saws. Single-handed large-toothed saws 4 to 7 ft. long, are used for sawing out blocks in some soft building stones. These saws are used only for vertical cuts in stones like the Bath and Beer stones, some of the Wealden sandstones and Gatton stone. In the Bath and Beer quarries a hole or " jad " is first made with

picks below the roof for admission of the saw, which then makes its vertical cut of the required depth and the block is raised by wedging.

Much greater speed of production and in some cases

Fig. 19

QUARRYING WITH THE "HARDY SIMPLEX" ROCK DRILL

much less waste is made by the employment of more elaborate mechanical appliances; among the more important of these are power drills, channelling and gadding machines, and the wire saw.

The Wire Saw. This appliance is only employable

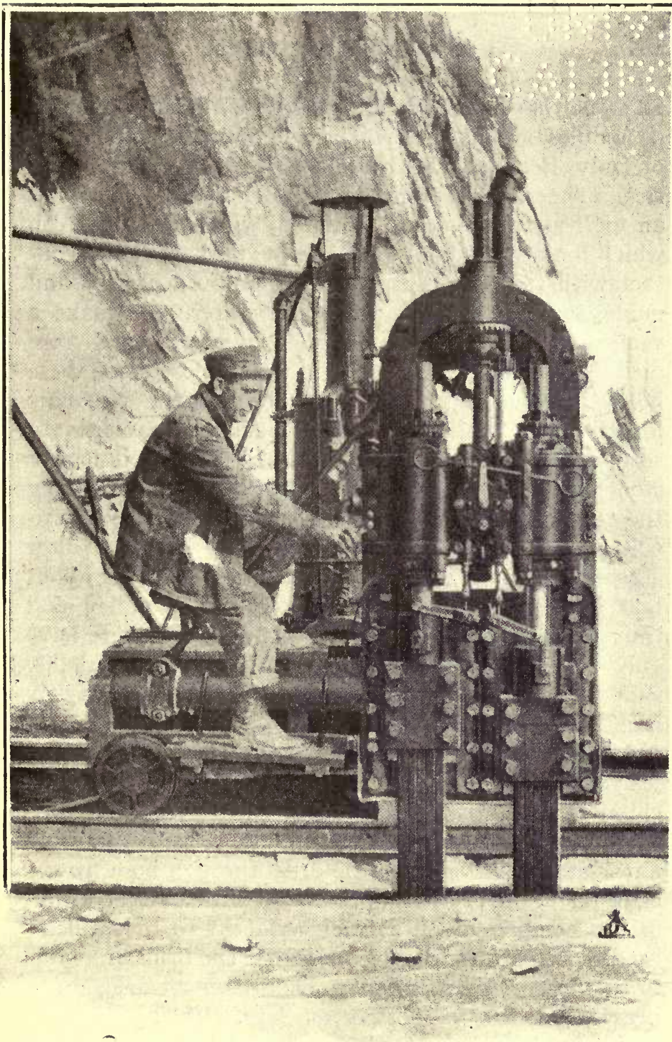


Fig. 20

SULLIVAN "DUPLEX" CHANNELLER

on stone that is quite free from occasional hard minerals or nodules, and is used mainly in the marble quarries of Italy, Belgium, and France, also in some slate quarries. The process originated in Belgium. The saw is an endless, three-strand, twisted wire of hard steel, which makes a cut by being kept taut while in contact with stone as it travels over grooved pulleys and guides carrying with it sand and water. To make a vertical cut two holes are drilled out by a large core drill, or by hand, at each end of the proposed cut; these holes take the descending pulleys bearing the wire; cuts in other directions are made in a similar manner. In soft stone the cut may be over 100 ft. long but in harder stone it must be much shorter. The necessity of making the terminal pits may be obviated by using the Monticolo penetrating pulley, which having only a shallow groove for the wire, allows the latter to project for about half its thickness while passing over the pulley and thus can cut while doing so. It is necessary to have only a small diameter borehole to take the pulley support at each end of the cut instead of the more costly large hole. See Figs 17 and 18.

Machine drills. In making holes either for plug and feather or for blasting, hand-drilling with the jumper or chisel is to a great extent superseded by power drills of various kinds. These are actuated by compressed air or steam delivered to the drills through hose from a central station; or by compressed air with an electrically-driven compressor on a truck adjacent to the drill; or by direct application of electricity. The drills are made in the form of light one-man, hand-hammer drills, or in heavier models supported on legs. Their action is rapid and they are easily controlled. Some of them strike 2,000 blows per minute and will cut 150 3-in. by $\frac{5}{8}$ in. plug and feather holes in hard granite in an hour.

Some forms have a hollow steel bit instead of a solid one which facilitates the removal of dust and chips by water or air. See Figs. 6, 14, 15.

The Gadder is a much heavier type of rock drill fixed to a heavy movable carriage in such a way that it can drill holes in various directions.

The Quarry bar is another device for supporting one or more drills; it consists of a stout horizontal bar, 8 to12 ft. long supported at the ends. The drills can slide along the bar, a convenient arrangement for making rows of plug holes. See Figs. 6 and 9.

Fig. 21

V W CUTTER FOR "DUPLEX" CHANNELLER

The Channeller. This is a machine for making a continuous open cut or channel, instead of a series of holes. It consists of one or more power-driven drills on a heavy carriage running on light rails; the machine travels backwards and forwards over the channel until it is cut to the required depth. It will cut a $1\frac{1}{2}$ in. channel to the depth of 6 ft. Some machines with a rigid head will cut only vertically, others with a "swivel" head will cut at various angles. Channels can also be cut with the ordinary drills or with the quarry bar by making the holes near together and then breaking through the partitions with a special "broaching" bit.

Blasting. In order to loosen and bring down large

quantities of rock at a relatively small cost blasting is necessary. This is an operation requiring more skill and knowledge for its successful performance than is generally supposed. These, with other matters, have to be taken into consideration in deciding the plan to be adopted: the hardness and toughness of the rock, frequency and direction of all planes of weakness, the number of free faces, the amount of stone to be broken and the kind of result required. Upon these will depend the number, depth, and distribution of the shotholes to secure the proper distribution of the force to be applied, the kind and amount of explosive used, the method of tamping, the kind of fuse and mode of firing.

In some quarries the plan is to employ very large blasts at long intervals, enough stone being brought down to occupy a year or two in its removal. For this purpose a gallery is cut back from the face of the quarry and at the desired distance from the face cross galleries are run right and left parallel with the face, to be used as chambers for the explosive; or the chambers may be made in other ways as circumstances dictate. The chambers are then carefully filled with gunpowder, charges of 5 to 10 tons or more being employed, electric or safety fuses are laid, the powder is protected from damp and then the remaining portion of the galleries is filled with turf and earth near the explosive and further away with cemented masonry. When the explosion takes place there is not nearly so much noise and disturbance as might be expected; the action seems to be rather slow, but the results are striking, tens of thousands of tons of stone are shattered. With a blast of this kind at Yr Eifl quarries 10 tons of black powder distributed between two chambers brought down stone estimated at 200,000 tons. The method

was used at the Furnace granite (quartz-porphyry) quarries, Lochfyneside, in 1855.

Another way of breaking a large mass of stone is by

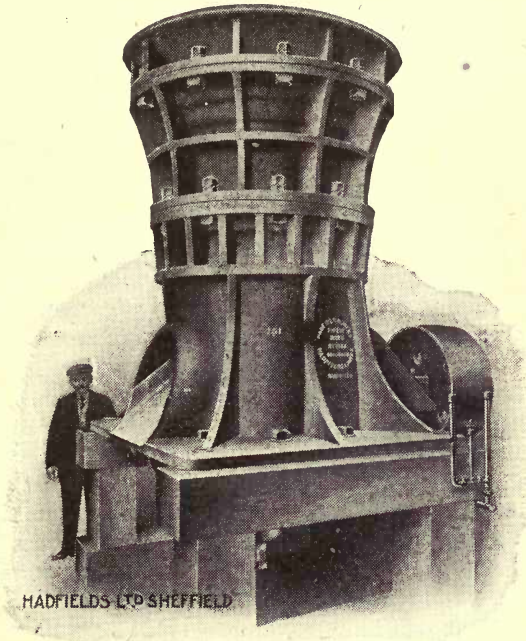


Fig. 22

" HECLON " GYRATORY STONE-BREAKER

firing at the same time the charges in a large number of shotholes, distributed over the quarry face so as to obtain the maximum effect. For this purpose a " simultaneous fuse " is used, which links up all the holes with a single electric shot-firer.

In general, blasting is carried out by drilling shotholes by hand or machine, as and where they are required, care being taken to make the hole away from joints and broken stone but in such a position as to take advantage of weak places. Shotholes of a yard or so depth are 1 in. to $1\frac{1}{4}$ in. diameter; if of greater depth, say, 20 to 30 ft., the hole commences at 2 to 4 in. and may decrease to as little as $\frac{3}{4}$ in., but this depends upon the explosive to be used. When ready the hole is dried, about $\frac{1}{2}$ oz. of powder is inserted through a zinc funnel, then the fuse is put in, followed by the remainder of the charge; finally it is "tamped" or sealed up and left ready to be fired. When an explosive other than black powder is employed it is inserted in the form of a stick or cartridge. Care has to be exercised in tamping that the charge is not fired by the generation of sparks from the tools or from the heating of the enclosed air by undue compression. The materials used for tamping vary with the explosive, brick dust, dried clay, sand and water are employed. The depth of shotholes is regulated by the result required, the object being to place the charge where it will exert the whole of its force usefully. The amount of charge used will depend upon the number of free faces around the hole, thus, if with one free face the charge is 1 lb., with two free faces it will be $\frac{1}{2}$ lb., with three it will be $\frac{1}{3}$ lb., and in splitting a detached block with a "pop" shot it will be only $\frac{1}{6}$ lb.

Explosives. There is now a considerable choice in explosives although the amount of gunpowder employed far exceeds that of all the others. Among other explosives the following are the most freely used; Ammonal, gelignite, cheddite, blasting gelatine, gelatine dynamite, monobel, bellite, steelite, dynamite, oaklite. The choice of explosive is inflenced by its action on the particular rock and by the relative cost of drilling; in

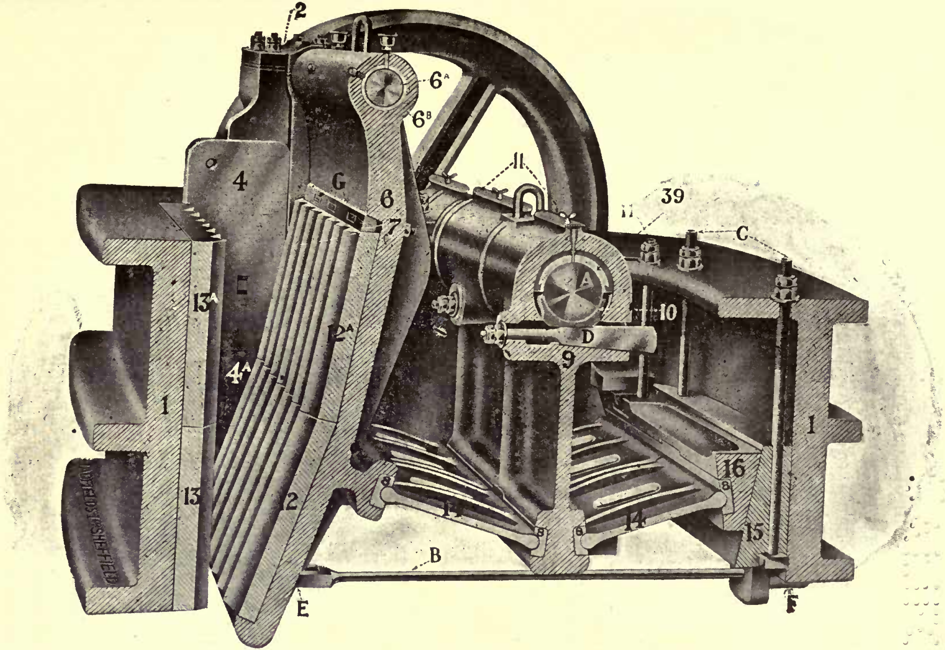


Fig. 23

SECTION OF HADFIELD'S SOLID STEEL CRUSHER, "BLAKE" TYPE

any case too much shattering of the stone is to be avoided. A high explosive may be preferred for blasting a hard rock to save drilling costs, and in a very soft rock because gunpowder would be too slow to exert sufficient force. Gunpowder is not suitable in wet holes.

Fuses are of various kinds; the simplest is a straw filled with fine powder, this may be replaced by a tin pipe or a squib; a much safer form is the ordinary rope fuse, made to burn at different rates. These methods of ignition are now to a great extent displaced in large quarries by electric shot-firing; in the high tension form a spark is caused to pass between two terminals surrounded by priming which ignites a detonator; in the low tension form the priming is ignited by a glowing wire. The explosion circuit is controlled by means of a primary battery or magnets, or better, by a hand dynamo.

With gunpowder the ignition is direct, the action slow and the tamping must be tight; with the high explosives a detonator is necessary, the action is rapid and the tamping must be light.

Springing. Very effective blasting may be obtained by using a single deep hole and enlarging the base by firing a succession of "springing" shots, beginning with small charges of dynamite and gradually increasing them until a fairly large cavity is made; the debris must be removed after each shot. Finally a charge of 200 to 300 lb. of gunpowder is put in the hole.

Blasting for Dimension Stone. It has been found that if the shothole, instead of being round is in the form of a flattened ellipse and the stone is free on three sides, a blast will tend to fracture the stone in the direction of the long axis of the ellipse. A single hole or a row of them may be employed. In the Knox and Westwood

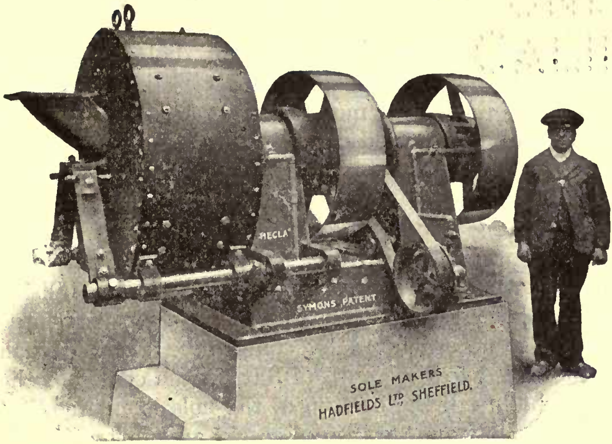


Fig. 24

"HECLA" DISC-CRUSHER

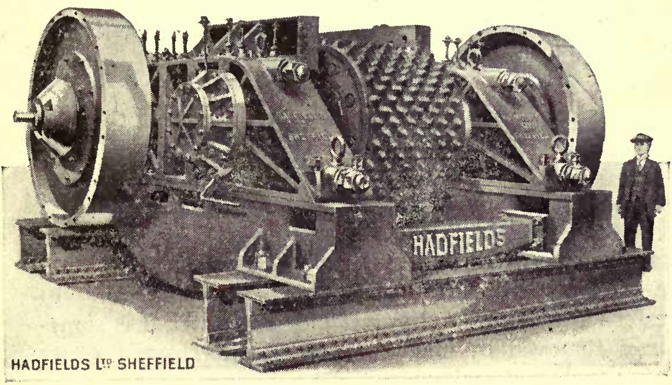


Fig. 25

HADFIELD'S HIGH-SPEED ROLLER

systems of drilling this kind of hole it is first made round and then opened at opposite sides by means of reamer bits, which must be kept accurately in the direction of the desired crack. In the Githens system an oval or oblong hole is made in one operation by using specially shaped drill bits.

Compressed Air. An extremely interesting method of quarrying granite is employed at Mount Airy, North Carolina, where, taking advantage of a sloping hillside and the sheeted structure of the rock (p. 52) very large areas of stone are lifted by compressed air. A small hole is drilled to the depth of 8 ft. in the centre of the area to be lifted, the bottom of the hole is enlarged by springing shots and horizontal cracks are started by the explosion of repeated small charges of powder until they have spread from the holes for about 100 ft. An air compressor, producing about 100 lb. pressure, is then connected to the hole by a pipe and air is gradually forced in. Sheets of granite several acres in extent may thus be cheaply raised.

Undercutting. In some Silesian quarries great quantities of stone are brought down by undercutting the face and temporarily supporting the overlying mass with props which are later removed suddenly by an explosion.

Handling the Stone and its Removal from the Quarry. Some soft rocks such as clay, gravel, soft shale and chalk may be excavated and put into trucks in one operation by means of a steam digger or navvy (see Fig. 16). In water-logged sand and gravel pits the material is sometimes removed by steam grabs, working from floating rafts; such materials may also be dredged.

Stone quarried in bulk in many large quarries is shot from a bench directly into full-gauge railway trucks; but where the stone has to undergo some operation before marketing smaller quarry trucks are used when

the distribution of the plant and shape of the ground permit. From a single long face, or from the several benches of a large quarry the truck or tram lines will converge on the crushers, kilns or depot, as the case may be. From deep quarries an inclined haulage tramway is often employed leading from the quarry floor to the bank. The system may be (1) *single rope* haulage, provided with one winding drum at the top, the empty trucks descending by gravity.

(2) *Main and tail haulage.* In a long track with

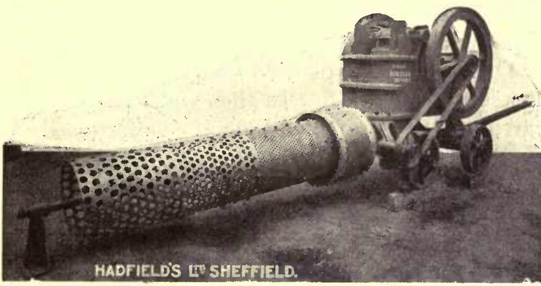


Fig. 26

PORTABLE BREAKER WITH SCREEN

variable gradient the empty trucks cannot return simply by gravity, therefore another drum is required at the foot of the incline to haul them back.

(3) *Endless rope* haulage in which the trucks are attached when required to an endless wire rope which moves continually in one direction over a pulley or drum at each end of the track.

Cableways, Wire-rope Conveyors. In many situations it is more convenient to remove the stone by means of carriers on an overhead wire rather than on rails on the ground. The " fixed rope " system is the one most

in use; in this two fixed wire ropes, supported on standards, are employed, one for the out journey, the other for the return; on these the carriers, supporting buckets, are drawn by a light endless travelling rope, which is wound on a "driving" drum at one end of the course and on a "tension" drum at the other end. The carriers are attached to the travelling rope by grips of various kinds. The speed is 3 to 4 miles an hour, and on moderate lengths as much as 700 tons can be carried in a day; the system can be used on steep gradients. In the "running rope" system the endless supporting wire rope itself moves the carriers which are gripped to it. This system is not used on inclines of more than 1 in 3 or less than 1 in 6. In the "telephrage" system the carriers are propelled along a fixed rope by electro-motors.

By the addition of a "fall pulley" to the carrier the rope-way can be employed for hoisting loads as well as transporting them. This arrangement, called a "blondin," is of great use in deep quarries. See Fig. 5.

For moving blocks of stone within the quarry pulley blocks, crabs or winches, screw-jacks, lewises, chains to pass round the blocks or to be used with "dogs," are employed. Cranes are essential; both derrick cranes and those with a fixed jib, actuated by hand and by steam or electric power, are used in quarries; in stone and dressing yards overhead travelling cranes, gantry and cantilever-cranes are generally employed.

CHAPTER XV

PREPARATION OF STONE FOR THE MARKET

CERTAIN classes of stone are ready for their market as soon as they are quarried, others require more or less special preparation: for example, the stone required for roads, building and decoration.

Road stone includes macadam, chippings and setts. In former days all macadam was hand broken, this was at best a slow process, a man could only make $\frac{1}{2}$ to $\frac{3}{4}$ of a cubic yard of broken basalt or granite, or about 3 cubic yards of limestone in a day. Now there is little hand-broken stone. When the stone has been broken by hammers to a convenient size for handling it is conveyed to a *crusher* of the "jaw" or "gyratory" type. See Figs. 22 and 23. In the jaw crusher are two heavy vertical plates of hardened steel, with vertical grooves so arranged that the ridges on one are opposite the hollows on the other; one is fixed while the other is moved by toggles to produce a series of blows on the stone, which is fed between the plates from a hopper. The jaws can be replaced when worn. The gyratory crusher is a heavy conical vessel containing a conical crusher moving on an eccentric so as to give the stone a succession of squeezes.

These crushers usually require modification to suit the type of stone, and since the product in the case of some stones is not sufficiently cubical a *crushing roller* is also employed. See Fig. 25. The rollers may be toothed or smooth; they are effective in giving the required shape to the broken stone and one machine can handle as much as 50 tons an hour.

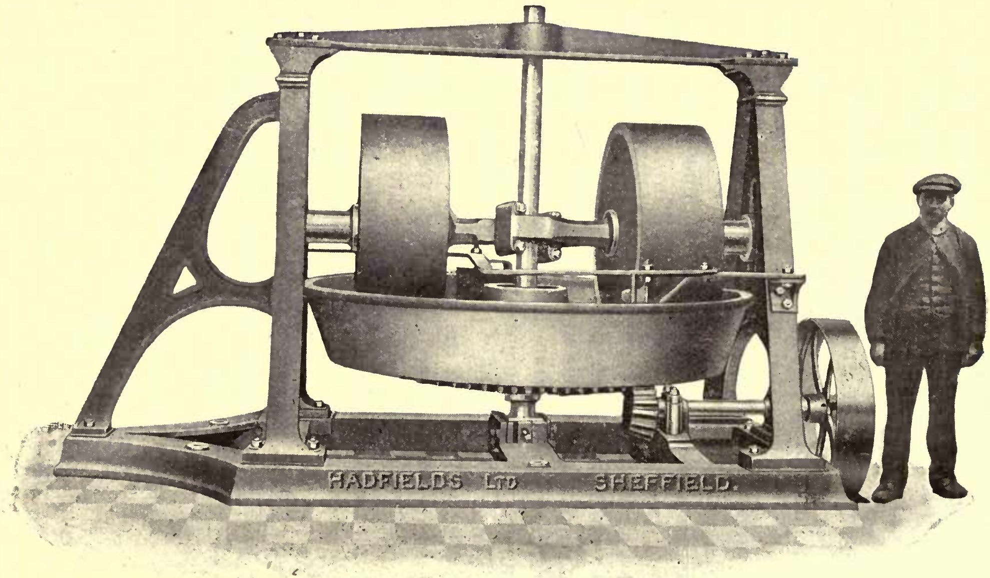


Fig. 27

UNDER-DRIVEN PAN MILL

After passing the crusher or roller, the broken stone is sorted according to size by being passed through cylindrical *screens* composed of perforated plates of

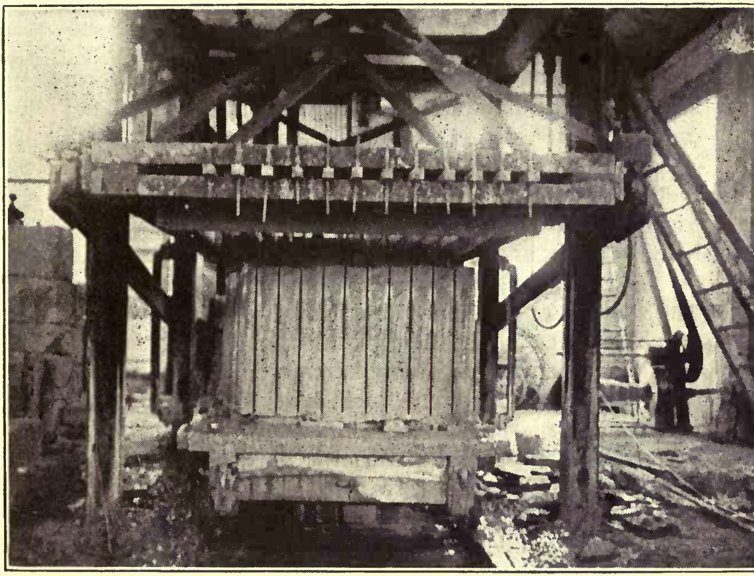


Fig. 28

GANG SAW CUTTING UP A BLOCK OF BATH STONE

mild or manganese steel. They are made in the form of single long cylinders (Fig. 26) or concentric cylinders, the coarsest perforations being on the inner one. The screens can pass 20 to 30 tons of stone per hour.

From the screens the graded stone is removed by bucket elevators or is distributed by a system of shoots

to the storage bins, which are arranged to discharge directly into railway wagons.

Setts are usually made by hand with hammers, a method requiring skill and experience. A machine has been invented in Sweden in which two power-driven hammers, controlled by levers, prepare the stone for the final dressing by hand.

Building stone is *dressed* or given the required form and surface by hand or machine, or by both. In hand dressing soft stones, toothed saws may be used, either single or double-handed; for mouldings a small toothless saw or thin iron plate is occasionally employed, together with sand and water. Harder stones, after being roughly shaped by spalling with a hammer, axe, or pick, are finished with chisels of various shapes. The spalling or scabbling hammer has square faces and weighs about 22 lb., the pick has pointed faces and is usually lighter, the scabbling hammer is also made with one square face and one pick face. These tools are employed for granite. An even but "pock-marked" surface can be produced with the pick, a finer surface by using the toothed or serrated pick. One of the most useful tools for granite dressing is the *axe,* a fairly heavy hammer with wedge or axe-shaped cutting faces; this makes a surface covered with parallel ridges and depressions; for very fine work of this kind the patent axe is used, this is made by binding together a variable number of steel plates with cutting edges.

An even surface may be made on soft stones by the "drag," a sort of comb; but on all kinds of stone a smooth surface is produced by rubbing with sandstone blocks and sand. Mouldings and other forms of surfaces are made by hand with chisels of different shapes, from the pyramidal-pointed, "point" or "puncheon" to the broad "boaster."

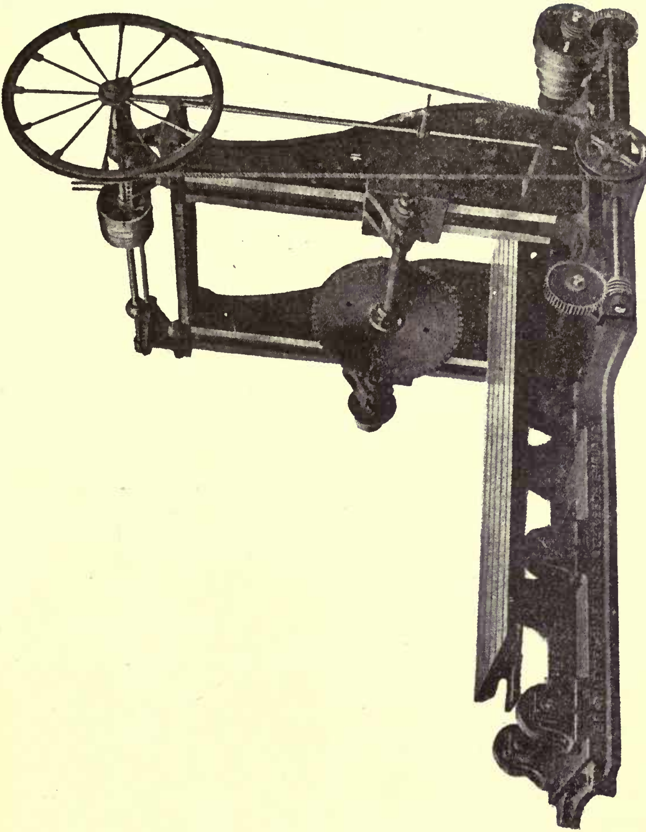


Fig. 29
DIAMOND STONE SAW

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Of the mechanical adjuncts to the dressing yard the saw is the most generally useful. Machine sawing is performed by straight-bladed saws and circular discs, and by several special forms. The straight saw is a

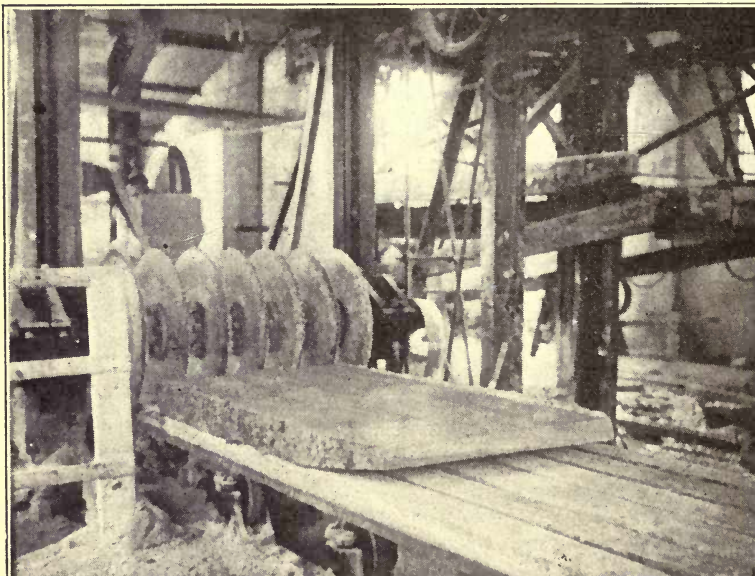

Fig. 30

CIRCULAR SAWS CUTTING DIMENSION STONE

Bath Stone Firms

thin strip of steel, 6 to 15 ft. long and 3 to 5 in. broad; several of these (a gang saw), from two to twenty, or in special cases up to 100, are suspended in a rectangular frame, parallel to one another, at adjustable distances. The frame is hung by suspension rods and power is supplied to give it a short too and fro motion

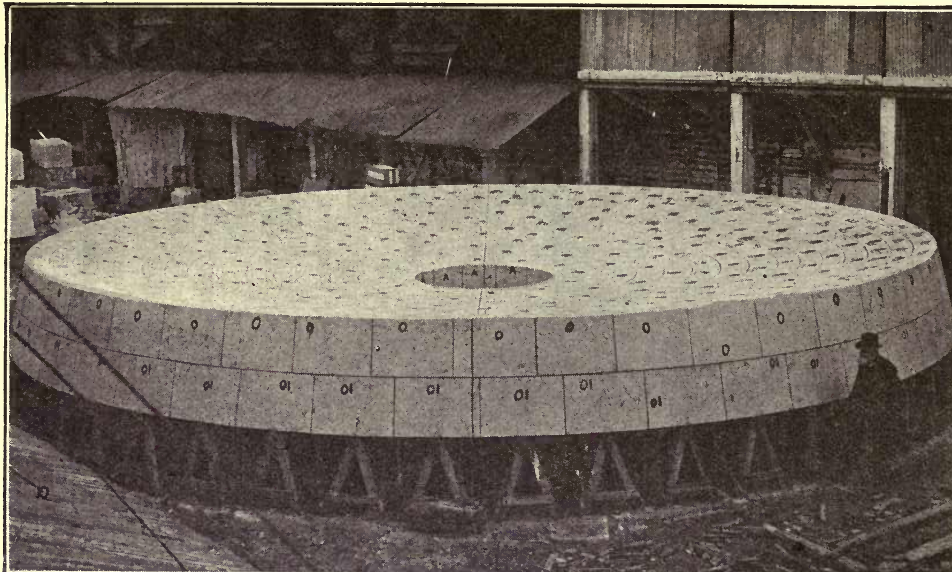

Fig. 31

INVERTED DOME FOR THE QUEEN VICTORIA MEMORIAL, CALCUTTA

This shows how the dressed granite is "dry set" in Messrs. Freeman's yard, before export

of 8 in. to 1 ft., at the rate of 150 to 180 strokes per minute. The saws descend vertically as they make their cut, under constant pressure, while being regularly fed with an abrasive agent and water. The abrasive agent is sharp sand, carborundum or chilled steel shot, also called "diamond grit," and supplied in numerous grades either rounded or angular. The water is delivered in the form of spray or drops by a reciprocating arrangement, along the length of each cut. The speed of cutting depends on numerous factors, but as a rule a soft stone like Portland is cut about three times as fast as marble and six times as fast as granite. The saw-blades may be perfectly straight and smooth or they may be corrugated or notched in various ways. The Lansdale patent saw differs mainly in its action, which causes it to be depressed at the end of each stroke as is done in using a cross-cut saw. See Figs. 28 and 36.

The "Chase" saw, an American patent, is a flat saw composed of a variable number of pivoted blades acting in unison and cutting by their ends instead of by their sides. The cut made by a set of such blades is an inclined one progressing in a series of shallow arcs.

Circular saws take the form of thin discs of steel, the thickness of which depends on the diameter and may be $\frac{1}{8}$ to $\frac{1}{4}$ in. When not provided with fixed abrasive cutters it is fed with water and a loose abrasive as in the gang saw. Fig. 30. The more powerful saws of this kind are supplied with a number of cutting diamonds or borts fixed securely in sockets on the rim in one or more rows; for instance, Anderson's patent diamond saw, if of 5 ft. diameter, carries 126 diamonds in three rows of forty-six each, the blade is $\frac{1}{4}$ in. thick, it can be run at 150 revolutions per minute with 5 horse-power. Diamond saws are made in various diameters and the diamonds are selected according to the class of work

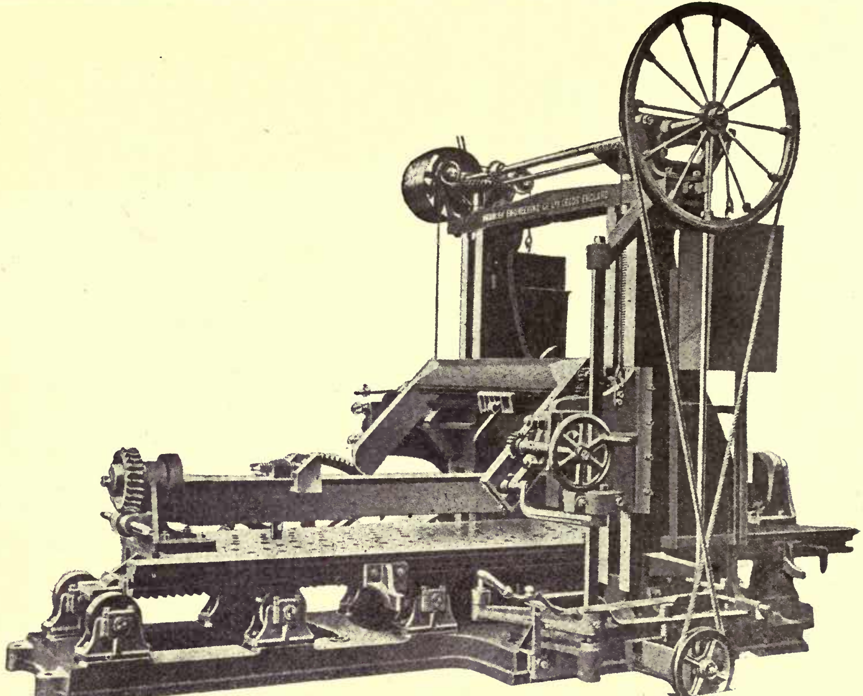

Fig. 32

PLANING MACHINE

required. See Fig. 29. A cut of 6 in. per hour is possible in hard stone. Two or more saws may be fixed on the same spindle. The Bramley Engineering Company has devised a circular saw in the form of a circular bent sheet to rotate horizontally, for cutting out grindstones. Band-saws have not been extensively employed for stone cutting; Leboyer's form of band-saw is composed of short flat links, each built up of three thin sheets of steel rivetted together. Wire saws are used in some yards for slicing blocks. (See p. 102.)

For dressing stone there are moulding and planing machines, generally consisting of a heavy rigid holder for the cutting tools with a travelling table to carry the stone forward against them. See Fig. 32.

Lathes are required for turning columns, these must be of large capacity to deal with columns which are frequently 30 to 40 ft. long, and occasionally special lathes are built to turn out columns of twice this length and 4 to 5 ft. in diameter. The cutters are in the form of chisels fixed in suitable holders on both sides or above the column of stone, or they take the shape of circular discs with bevel edges, revolving on spindles on either side of the column. For small ornamental objects small treadle lathes are still employed in some districts.

Sawing, turning, moulding and smoothing flat surfaces can all be done by means of carborundum made up in the form of wheels of various shapes; smoothing is performed by a carborundum-faced drum under which the slab of stone or marble is made to pass. The use of this method is more prevalent in America than in Britain.

For giving a smooth surface to small blocks of stone large horizontal iron discs are used, upon which the stone is held while the moving disc is charged at intervals with sand, or other abrasive, and water. Fig. 33.

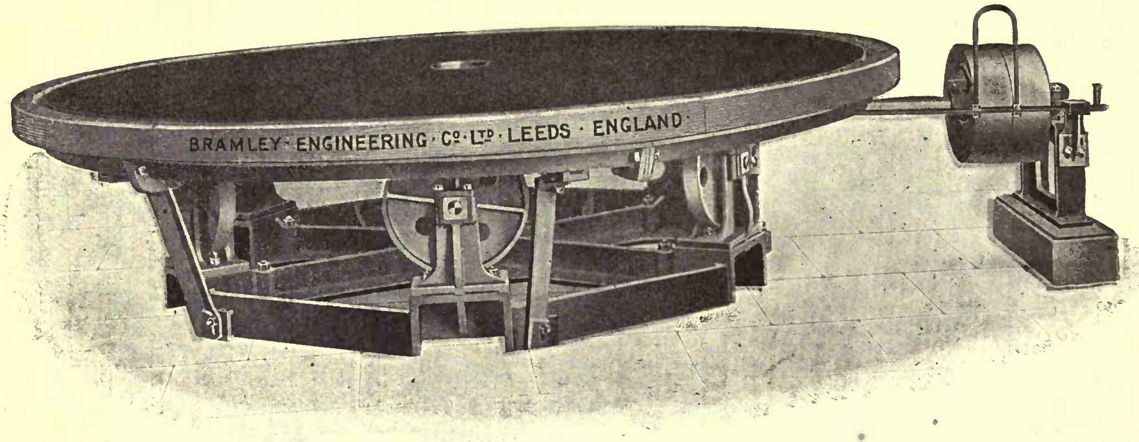

Fig. 33

RUBBING BED FOR MARBLE OR STONE

For smoothing large flat surfaces, or for a number of slabs of the same thickness, a large octagonal iron frame

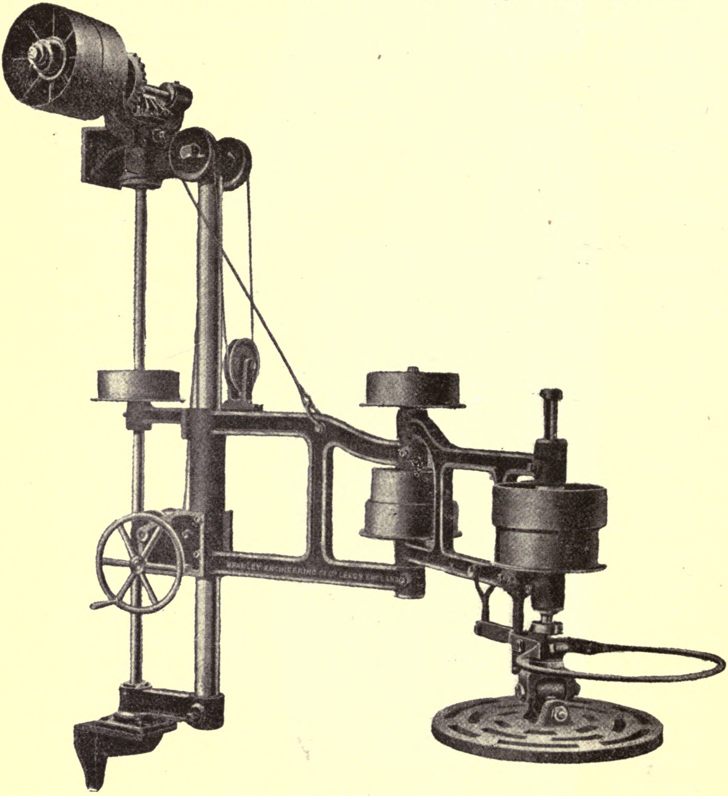

Fig. 34

JENNY LIND POLISHING MACHINE

supported from above is given an eccentric rotary motion, and the stones are placed beneath it on a carrier. For polishing the same machine is employed,

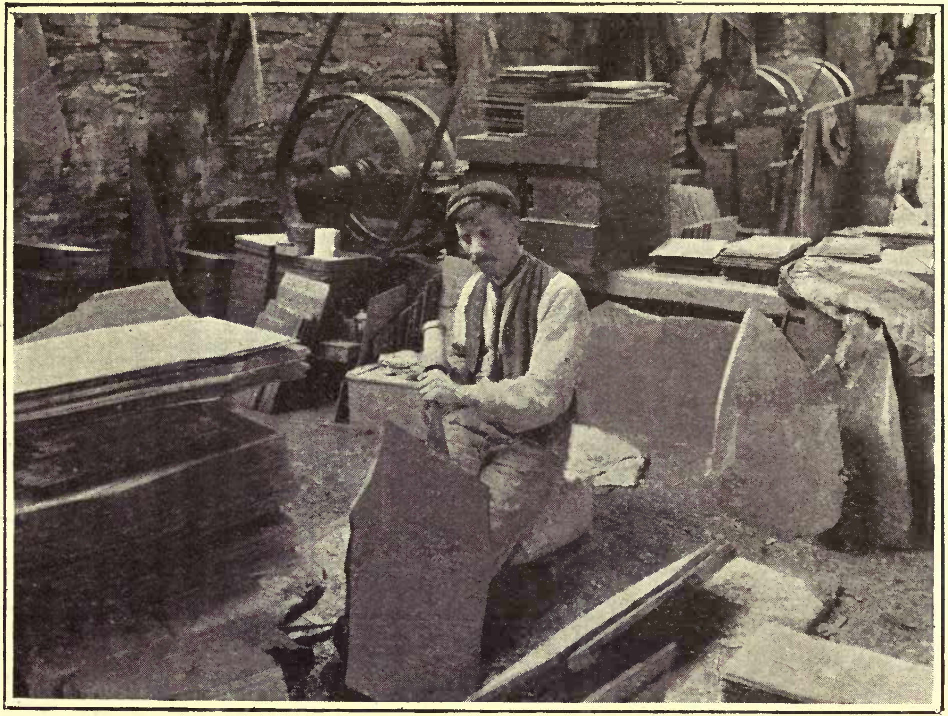

Fig. 35

SPLITTING ROOFING SLATE : CUTTING MACHINES IN THE BACKGROUND

but its lower face is covered with rope or cloth. Pieces of granite or marble that cannot be placed beneath the rotating bed can be polished by the "blocking" machine, which consists of a heavy mass covered with felt and given a too-and-fro motion. Another convenient polishing instrument is the "spinner," a small iron disc, suitably padded, and caused to revolve rapidly in contact with the object to be polished; it is connected to the power supply by a universal joint or flexible connection. Larger areas are usually polished by the "Jenny Lind." (Fig. 34.)

The abrasive powders employed for polishing differ according to the character of the stone, and coarser powders are used in the earlier stages, finer in the later ones. Compact close-grained marbles are usually polished with putty powder (oxide of tin) or rouge; but marbles with harder parts and irregularities require in the earlier stages, emery or emery and lead filings; tripoli, diatomite and various selected sands are also occasionally employed before the putty powder. Pumice, glass, alumina, alundum and other products of the electric furnace are also used. For small articles of very hard stone powdered bort may be used for smoothing.

Carving of stone is performed either with chisels and hammer and finished in the more intricate parts with rifflers and various other small tools, or it is done wholly or in part by mechanical appliances, such as pneumatic graving tools, on the same principal as the pneumatic drill (p. 104) but much smaller. These machines, with 50 to 100 lb. air pressure per square inch, will strike up to 3,000 small blows per minute. In another form of the tool a small rounded cutter is caused to rotate rapidly. For lettering and cutting shallow designs the sand-blast machine is sometimes

used. This consists of an air compressor and a receptacle for sand connected by pipes to a delivery jet. The air pressure must be moderate, and the sand should be sharp and clean and of such a degree of coarseness that

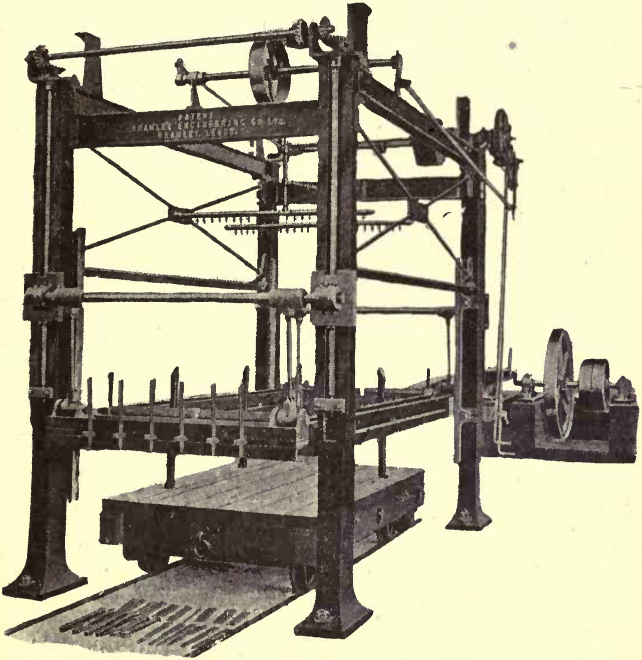

FIG. 36

FAST-CUTTING SAW FRAME FOR GANG SAWS

the bulk should pass an 80-mesh sieve and be held on a 100-mesh. Such a machine will cut a pattern on 10 to 40 square yards of surface in an hour, according to the hardness of the stone and the depth of the incision. Before using it those portions of the surface of the stone to be untouched are protected by a paper shield.

In order to increase the speed of polishing marbles various substances are occasionally added to the polishing powder such as oxalic acid or alum; finally to increase the appearance of polish a rubbing of wax is sometimes applied.

Marbles frequently contain hollow cracks and defects that are made good by "stopping" or filling with some substance that will take a polish and remain unnoticeable as long as possible. The art of mixing and applying stopping is quite an important one in connection with some marbles; needless to say the less stopping there is the better.

Slate-dressing. The methods employed in the preparation of slate differ in some respects from those used for other stones on account of the cleavage. Some quarries produce only roofing slate, others yield both roofing slate and slabs. In the preparation of slabs from the rough blocks saws are employed for squaring; larger blocks are cut by a circular saw set with steel nails on the periphery, the heads of which do the cutting; smaller slabs are cut with an ordinary-toothed circular saw or with a notched hand-saw. Slabs are planed to a true surface and given grooves or mouldings in a planing machine; a final "polish" being applied by rubbing with pumice. Mouldings are also cut by hand with chisel and mallet and finished with a file or emery.

Roofing slates are sawn in blocks of suitable length across the cleavage, and split with the cleavage to blocks of about 3 in. thick, and then split lengthwise, across the cleavage with a heavy hammer and stout "pillaring" chisel. The slab of slate thus prepared is then taken in hand by the splitter, who sits with it placed almost vertically against his knees, and with a broad thin "splitting" chisel and light wooden mallet carefully cleaves off sheet after sheet. Fig. 35. The

thickness of the sheets depends upon the character of the slate, some can be made very thin, others cannot be made less than $\frac{1}{4}$ in. in thickness. The split slates are trimmed to the nearest trade size with a straight-bladed "dressing" knife while they are held against a horizontal iron straight-edge, called a "travel." Dressing is also done by a machine resembling a pair of heavy shears or guillotine. The portions to be trimmed off are marked by a scratch with a nail fixed in the end of a notched "measuring" stick.

Slates will not split readily if the quarry-water has been allowed to dry out of them.

Slates are graded at the quarry according to size and weight, and as "firsts," "seconds," and "thirds," as regards quality, that is, their thinness and freedom from flaws in texture or colour. They are sold at the quarry by the "long-tally" of 1,260 to the thousand. Many different sizes are made bearing special trade names, thus "Princess," 24 × 18 in.; "Duchess," 24 × 12; "Small Duchess," 22 × 12 to 20 × 12; "Countess," 20 × 10 to 18 × 10; "Small Countess," 18 × 9 to 16 × 12 and 16 × 9; "Ladies," 16 × 8 and 14 × 12 to 14 × 7.

The so-called "tile-stones" or slate stones are split not along the cleavage, which does not exist in these rocks, but along the bedding. Some fissile sandstones can be split to the required thickness for roofing as they are required, others, such as the "Colyweston slates," have to be exposed in blocks on the surface of the ground during winter; if there are frequent short frosts they will split thin in the spring, but if there is not sufficient frost, or the freezing is long and continuous, they will not split so thin. In any case they are much heavier than slates and they require a stronger support in the roof.

APPENDIX

A few Books on Stone and Allied Subjects.

Geology . .	W. W. Watts, *Geology for Beginners*. London. G. A. J. Cole, *Rocks and their Origins*. Cambridge, 1912.
Mineralogy .	F. Rutley, *Elements of Mineralogy*. London, 1916. H. A. Miers, *Mineralogy*. London, 1912.
Petrology .	A. Harker, *Petrology for Students*, 6th Ed. Cambridge, 1918. Hatch & Rastall, *The Petrology of the Sedimentary Rocks*. London, 1913.
Building Stones .	J. A. Howe, *The Geology of Building Stones*. London, 1910. G. P. Merrill, *Stones for Building and Decoration*, 3rd Ed. New York, 1903. C. H. Richardson, *Building Stones and Clays*. Syracuse, N.Y., 1917. Ries & Watson, *Engineering Geology*. New York, 1914.
Marbles . .	M. Darras, *La Marbrerie*. Paris, 1912. W. G. Renwick, *Marble and Marble Working*. London, 1907. G. H. Blagrove, *Marble Decoration*. London, 1888. J. Watson, *British and Foreign Marbles*. Cambridge, 1916.
Quarrying .	Greenwell & Elsden, *Practical Stone Quarrying*. London, 1913. Karl Weiss, *Technik der Steingewinnung und Steinverarbeitung*. Berlin, 1915.

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